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Carnot

Carnot

December 1995

PISCES Field Chemical Emissions Monitoring Project: Site 121 Emissions Report

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Final Report, December 1995

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October 27, 1994

Mr. William H. Maxwell, P.E. (MD13)
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Dear Mr. Maxwell:

In response to the Clean Air Act Amendments of 1990, the Electric Power Research Institute (EPRI) initiated the PISCES (Power Plant Integrated Systems: Chemical Emissions Studies) program to better characterize the source, distribution, and fate of trace elements from utility fossil-fuel-fired power plants. As part of the PISCES program, the Field Chemical Emissions Monitoring (FCEM) program has sampled extensively at a number of utility sites, encompassing a range of fuels, boiler configurations, and particulate, SO_2, and NO_X control technologies. EPRI is actively pursuing additional FCEM sampling programs, with 29 sites either completed or planned.

This site report presents a preliminary summary of data gathered during a sampling program conducted at one of the FCEM sampling programs - Site 121. Site 121 consists of an 330 MW boiler burning natural gas. NOx controls are the only air pollution control devices at Site 121 and include flue gas recirculation (FGR), overfire air (OFA) ports, and off-stoichiometric firing utilitizing burners-out-of-service (BOOS).

The Site 121 sampling and analytical plan included some differences from the standard sampling and analytical plans at other FCEM sites. Specifically, the California Air Regulatory Board (CARB) methods were used to sample for the volatile organic compounds (VOCs) and the polycyclic aromatic hydrocarbons (PAHs). In the multi-metals trains, the filter and associated rinses were combined with the impinger fractions in order to obtain lower detection limits - thus only total metal concentrations are available, instead of differentiating between particulate and vapor phase concentrations. Most of the metal values reported had significant background levels in the filters, making these values questionable.

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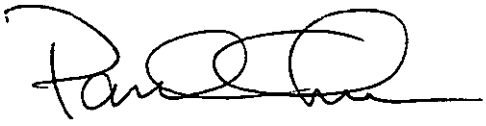
The primary objective of this report is to transmit the preliminary results from Site 121 to the EPA for use in evaluating select trace chemical emissions from fossil-fuel-fired steam generating plants. **It should be noted that the results presented in this report are considered PRELIMINARY.** As additional data from other sites are collected and evaluated, EPRI may conduct verification tests at this site. If this is done, the new data will be made available to the Environmental Protection Agency (EPA).

In addition to the raw data in the Appendix, the report provides an assessment of the material balances, discusses the data quality, identifies suspect data, and offers possible explanations for the questionable data. This report does not compare the results from Site 121 with the results from previous utility sites. Nor does this site report attempt to address the environmental and health risk impacts associated with the trace chemical emissions.

EPRI hopes that this site report is of assistance to the EPA in evaluating utility trace chemical emissions as well as the associated health risk impacts.

Sincerely,



Paul Chu
Manager, Toxic Substances Control
Environmental Control Business Unit

ABSTRACT

This report is one of a series sponsored by the Electric Power Research Institute in the area of trace substance emissions from fossil-fuel power plants. This report presents the results of a sampling and analytical study to characterize trace substances emissions at Site 121. Site 121 is a natural gas-fired boiler. The NO_x controls are the only air pollution control devices at Site 121 and include flue gas recirculation, overfire air, and off-stoichiometric firing utilizing burners-out-of-service.

The objective of this report is to transmit the detailed data to the U.S. Environmental Protection Agency (EPA) to assist the Agency in evaluating utility trace chemical emissions as well as the associated health risk impacts—as mandated in Title III of the 1990 Clean Air Act Amendments. This report does not attempt to compare the results with other sites. An assessment of data from all plants that have been tested is presented in the Electric Utility Trace Substances Synthesis Report (EPRI TR-104614).

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SECTION 1.0

INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

This report summarizes data gathered by Carnot at a power plant designated Site 121 for a program sponsored by the Electric Power Research Institute (EPRI), the Gas Research Institute (GRI) and the host utility. The objective of the Field Chemical Emissions Monitoring Project (FCEM) sponsored by EPRI is to measure the concentrations of selected inorganic and organic substances in the process and discharge streams of power plants. These data are being used to determine the fate and control of these substances.

The primary objectives of this report are to provide information on fuel composition and stack emissions and to evaluate these data according to the criteria outlined below. The information is presented in a format suitable for the U.S. Environmental Protection Agency (EPA) to use to study emissions from fossil fuel fired power plants, as mandated by the Clean Air Act Amendments (CAAA) of 1990. This report summarizes fuel and stack gas concentration data measured during the operation of an opposed-fired boiler firing natural gas. Sampling was conducted during April 1993.

Table 1-1 lists the substances of interest to the FCEM project which were measured at Site 121. Carnot conducted the testing and has prepared this report using the following procedures to evaluate the data:

- The type and quantity of quality assurance samples were reviewed to determine the confidence that can be placed in the results; and
- The QA/QC results were compared with data quality objectives to evaluate precision and accuracy.

Results are presented for each substance by individual run and as an averaged total. To demonstrate data variability, the 95% confidence interval about the mean is also presented. The confidence interval incorporates the combined process, sampling, and analytical variabilities.

1.2 SAMPLING AND ANALYSIS PROTOCOL

The sampling and analysis protocol for Site 121 is described in Appendix A. The FCEM program has attempted to employ standard sampling and analytical procedures when possible.

TABLE 1-1
FCEM SUBSTANCES OF INTEREST
SITE 121

Elements	Organic Compounds
Arsenic	Benzene
Barium	Toluene
Beryllium	Formaldehyde
Cadmium	Naphthalene
Chromium	Acenaphthylene
Cobalt	Acenaphthene
Copper	Fluorene
Lead	Phenanthrene
Manganese	Anthracene
Mercury	Fluoranthene
Molybdenum	Pyrene
Nickel	Benzo(a)anthracene
Selenium	Chrysene
Phosphorus	Benzo(b)fluoranthene
Vanadium	Benzo(k)fluoranthene
	Benzo(a)pyrene
	Indeno(1,2,3-cd)pyrene
	Dibenzo(a,h)anthracene
	Benzo(g,h,i)perylene
	2-Methylnaphthalene
	7,12-Dimethylbenz(a)anthracene
	3-Methylcholanthrene
	Polychlorinated Biphenyls (PCB)

Additional Evaluations:

VOCs (benzene, toluene and formaldehyde) at 37% of full load condition and at air preheater inlet O_2 levels of 3.75, 2.69 and 5.66%.

The methods used are comparable to those used at other FCEM sites with the following exceptions:

- Benzene and toluene samples were collected in Tedlar bags according to California Air Resources Board (CARB) methodology rather than using VOST sampling. At the time of sampling, there were some concerns with the VOST method. Previous experience indicates that Tedlar bag sampling gives adequate results.

- Exhaust gas metals were determined as the total per sample train rather than differentiating between particulate and vapor phase metals.

- PAH and PCB were collected and analyzed according to CARB methodology. These samples were analyzed using isotope dilution methodology by high resolution gas chromatography/low resolution mass spectrometry with selected ion monitoring (HRGC/LRMS-SIM).

- Triplicate on-line measurements of natural gas composition (major hydrocarbons plus O_2, H_2O, He, H_2, N_2, CO_2, CO, H_2S, COS) and heating value were performed for EPA Method 19 F-factor calculations. Additional single samples were taken for analysis of trace elements and species.

1.3 QUALITY ASSURANCE/QUALITY CONTROL

The completeness of the quality assurance data was reviewed to judge whether the quality of the measurement data could be evaluated with the available information. In general, the results of the QC checks available for Site 121 indicate that the sample results are well characterized. An evaluation of the accuracy, precision, and bias of the data, even if only qualitative, is considered to be an important part of the data evaluation. A full discussion of each of these components of quality can be found in Section 5.0.

Standard QA/QC checks for this type of sampling program involve the use of: (1) duplicate field samples and lab analyses, matrix spike and lab control duplicates and replicate tests to determine precision; (2) matrix spikes, surrogate spikes, and laboratory control samples to determine accuracy; and (3) field blanks, trip blanks, method blanks, and reagent blanks to determine if any of the samples were contaminated during collection or analysis. Most of these standard QA/QC checks were used on samples from Site 121. Some QA/QC checks do not apply to some types of analyses; for example, surrogate spikes do not apply to metals analysis. The absence of any of these "standard" quality control checks from the Site 121 report does not necessarily reflect poorly on the quality of the data but does limit the ability to measure the various components of measurement error.

1.4 DATA QUALITY

The available QA/QC results were compared to the data quality objectives shown in Section 5.0. QA/QC results outside the data quality objectives are noted and discussed, other quality assurance values are evaluated, and the potential effect on data quality is noted. The detailed information presented in Section 5.0 supports the conclusion that the data quality objectives were met with the following exceptions:

- There is a concern with the determination of arsenic in the exhaust gas samples. Precision of duplicate analyses was 61% RPD. Because the arsenic concentrations were low, blank levels were significant compared to the sample values. Laboratory blank corrections were 22% of the uncorrected value. Field blank levels were 73% of the uncorrected sample values.

- Metals run 2 was invalidated because the concentrations of chromium, copper and nickel indicated field contamination at 750, 940 and 410 μg/train, respectively. The entire run was invalidated since the results of these three trace metals indicated contamination of the sample.

- Because of low emissions expected from a gas-fired source, the interpretation of field blank levels becomes more difficult. Field blank levels were greater than 50% of uncorrected sample values for arsenic, lead, manganese, molybdenum and phosphorus. The only metals results where field blanks levels do not significantly affect the interpretation of emission values are barium, chromium, copper, nickel and vanadium.

- The results of the toluene analysis from VOC run 3A were not included in the average result. This sample contained 250 $\mu g/Nm^3$ of toluene compared to an average of 18 $\mu g/Nm^3$ for runs 3B and 3C. Contamination of sample 3A was considered likely.

- Formaldehyde results may be biased high as indicated by field blank levels. Three of six field blanks were higher than the sample values. Individual field blanks ranged from 39-60% of the uncorrected sample values. Although the precise extent of this bias cannot be assessed, it can be inferred from the field and trip spikes which, although they were within the method specification of 60-140%, had recoveries of 140 and 131%, respectively.

1.5 REPORT ORGANIZATION

Section 2.0 of this report briefly describes the plant and the sample locations. Section 3.0 discusses the results of the chemical analysis of the natural gas and flue gas streams. Section 4.0 discusses the results from additional tests conducted to determine the effect of unit operation on VOC emissions. Section 5.0 presents QA/QC and engineering evaluations of the

data. Section 6.0 presents example calculations, and a glossary of terms is provided in Section 7.0. The appendices contain information on sampling and analytical methods, stream concentrations, sampling data, process operation, error propagation equations, and detailed QA/QC data.

SECTION 2.0

SITE DESCRIPTION

This section presents a description of the test site, designated Site 121, and the sampling locations at this site.

2.1 FACILITY INFORMATION

The boiler at Site 121 is a Babcock & Wilcox (B&W) opposed-fired boiler rated at 330 MW gross. This forced-draft boiler is a double-reheat design and is capable of firing either natural gas or low-sulfur residual fuel oil. Tests were performed only on natural gas. Fuel oil had not been fired for at least one and one half years prior to this test program. Table 2-1 summarizes the configuration of the unit at Site 121. Figure 2-1 presents a process flow diagram of Site 121.

NO_x controls are the only air pollution control devices installed at this facility. NO_x controls installed at Site 121 include flue gas recirculation (FGR) to the furnace hopper, overfire air (OFA) ports above the top burner rows on the two walls, and off-stoichiometric firing utilizing burners-out-of-service (BOOS). During BOOS operation, the gas flow to the selected burners is shut off, but the air registers remain wide open. The local NO_x limit at Site 121 at the time of the test program was 125 ppmc (ppm corrected to 3% O_2).

2.2 SAMPLING LOCATIONS

Samples were taken from two process streams: the natural gas fuel and the exhaust gas. Figure 2-1 identifies the three sampling locations used for the test program.

A brief description of each sampling location follows:

- Natural gas was the only fuel stream sampled. Samples were collected at the main plant gas header, which supplies natural gas to several boilers, including Site 121. Due to sampling constraints, the gas stream specific to Site 121 could not be sampled. Gas at the main gas header, however, should be representative of the gas flow to Site 121.

- NO_x, CO, O_2 and CO_2 were continuously monitored through a 16-point probe array installed in the air preheater inlet duct.

TABLE 2-1
SITE 121 CONFIGURATION

BOILER:	
Maximum Gross Electrical Output, MW	330
Boiler Type	Opposed-fired
NO_x Emission Limit, ppm at 3% O_2	125
NO_x Controls	Hopper FGR
	Overfire Air Ports
	Off-Stoichiometric Firing (BOOS)
Fuel Type	Natural Gas
Fuel Methane Content, mole%(1)	95.5
Fuel Heating Value, Btu/scf at 68°F(1)	998

(1) Average values measured during sampling.

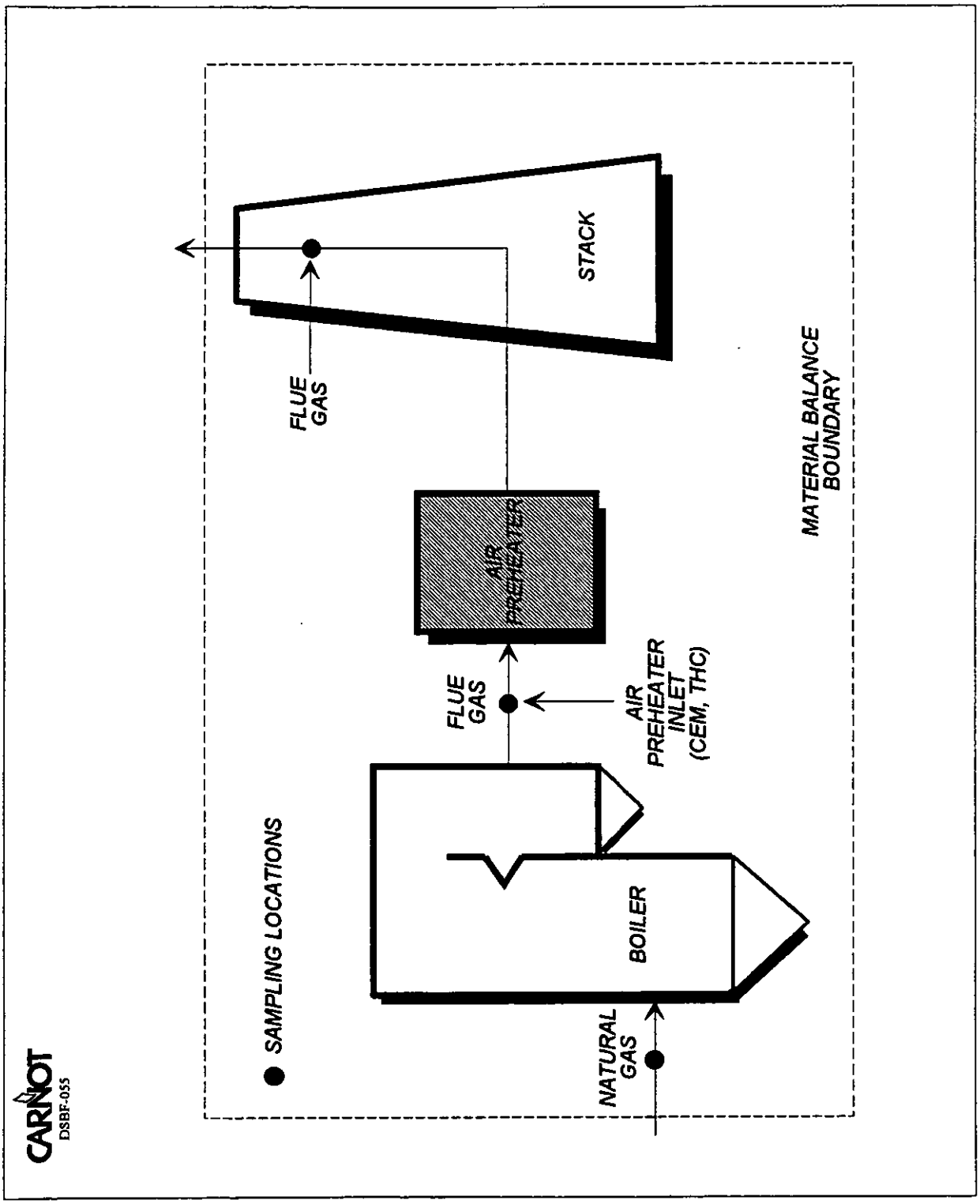


Figure 2-1. Process Flow Diagram of Site 121

- Total hydrocarbons (THC) were monitored at a single point in the air preheater inlet duct.

- Flue gas exiting the stack was the only discharge stream sampled. Flue gas samples were taken through four test ports installed on the stack. A total of 24 points were sampled for isokinetic tests according to EPA Method 1.

The procedures used for collecting, pretreating, and analyzing the samples from Site 121 are discussed in Appendix A. Table 2-2 presents an overview of the types of analyses performed on these streams.

2.3 PROCESS OPERATION DURING TESTING

The base PISCES test program (Runs 1, 2 and 3) was conducted at nominal full load. Average load during this base testing was 334 gross MW with normal boiler O_2 levels. Oxygen levels measured at the air preheater inlet averaged 2.85% for the three runs. All controls were operated in manual control, with the exception of the final steam temperature, superheater spray valve and forced draft fan controls.

All NO_x controls were in operation for the base tests, and the average NO_x emissions were 99 ppmc (ppm corrected to 3% O_2), or 1.12 lb/MW-hr. FGR was at normal conditions, the overfire air ports were fully open, and there were 10 BOOS.

Three additional tests (Runs 4, 5 and 6) were conducted to determine the effect of unit operation on VOC emissions. All three tests were conducted at minimum load, averaging 123 gross MW. However, boiler O_2 levels were varied for each of the tests with normal, low and high O_2 levels used for tests 4, 5, and 6, respectively. Oxygen levels, measured at the air preheater inlet, were 3.75, 2.69 and 5.66% for Tests 4, 5 and 6. As with the base tests, all controls were operated in manual control, with the exception of the final steam temperature, superheater spray valve and forced draft fan controls.

All NO_x controls were in operation for these additional tests, with normal FGR levels and overfire air ports fully open. For all three tests, there were 8 BOOS. Test 4 (normal O_2) produced NO_x emissions of 57 ppmc (0.72 lb/Mw-hr). Test 5 (low O_2) produced NO_x emissions of 46 ppmc (0.57 lb/MW-hr). Test 6 (high O_2) produced NO_x emissions of 80 ppmc (1.0 lb/MW-hr).

Further discussion of the process operation is provided in Section 5.1. Appendix E contains the process operation data.

TABLE 2-2
PROCESS STREAM ANALYSES PERFORMED

Stream	Metals[1]	Semi-Volatile Organics[2]	Volatile Organics[3]	Composition[4]
Natural Gas	✓	✓	✓	✓
Flue Gas	✓	✓	✓	

(1) Flue gas metals include the target species arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, phosphorus, selenium and vanadium. Metals analysis in natural gas include the target species arsenic and mercury.
(2) Semi-Volatile Organics include nineteen PAH and mono - through decachlorinated PCB isomer groups.
(3) Volatile Organics include benzene, toluene, and formaldehyde.
(4) Composition for natural gas analysis includes hydrocarbons, non-hydrocarbons (O_2, H_2O, He, H_2, N_2, CO_2, CO, NO, NO_x), sulfur compounds, oxygenated compounds, nitrogen compounds, halocarbons, radon and higher heating value.

SECTION 3.0

RESULTS

This section summarizes the data collected at Site 121 during the base test program with the unit operating at full load with normal O_2 levels. Because the focus of this report is on exhaust gas emissions, only natural gas characterization data and flue gas stream data are presented here in detail. VOC data collected during the unit operation tests are summarized in Section 4.0. Sampling, preparation and analytical methods are summarized in Appendix A. Detailed analytical data can be found in Appendices B and C.

3.1 SAMPLING SCHEDULE

Sampling at Site 121 was performed in April 1993. Figure 3-1 presents the sampling schedule for the test program at Site 121. Test numbers have been assigned sequentially and all tests conducted simultaneously have the same number. Additional designators indicate the sample train type and sampling location.

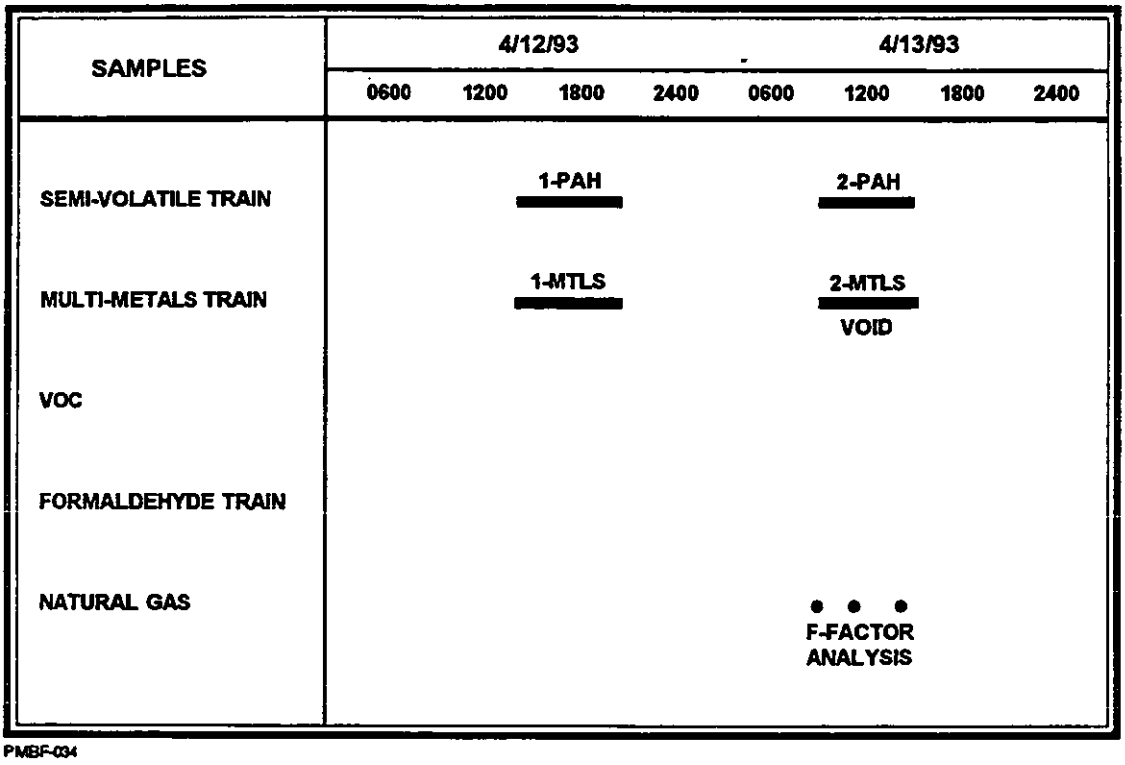
Four types of sampling trains were used to collect flue gas samples from the stack for the FCEM species of interest. These trains were: multimetals trains, semi-volatile organics trains, Tedlar bag samples for benzene and toluene and formaldehyde trains. Each multimetals and semi-volatile test required a full isokinetic traverse of the stack. Tedlar bag samples for benzene and toluene and formaldehyde samples were collected nonisokinetically at a single point in the stack.

3.2 DATA TREATMENT

Several conventions were developed for treating the test data and developing average concentrations of substances in the natural gas and flue gas streams. The conventions used in this report are consistent with the PISCES FCEM data treatment procedures.

3.2.1 Blank Corrections

The individual run measurements were corrected for the reagent blank analysis when it was available and when it is allowed by the reference method. If a reagent blank was not analyzed or was considered nonrepresentative, the measurement was corrected for a laboratory blank. The laboratory blank is not exposed to field conditions and contains only the chemicals needed for analysis so it is expected to be lower than the reagent blank. When the blank result



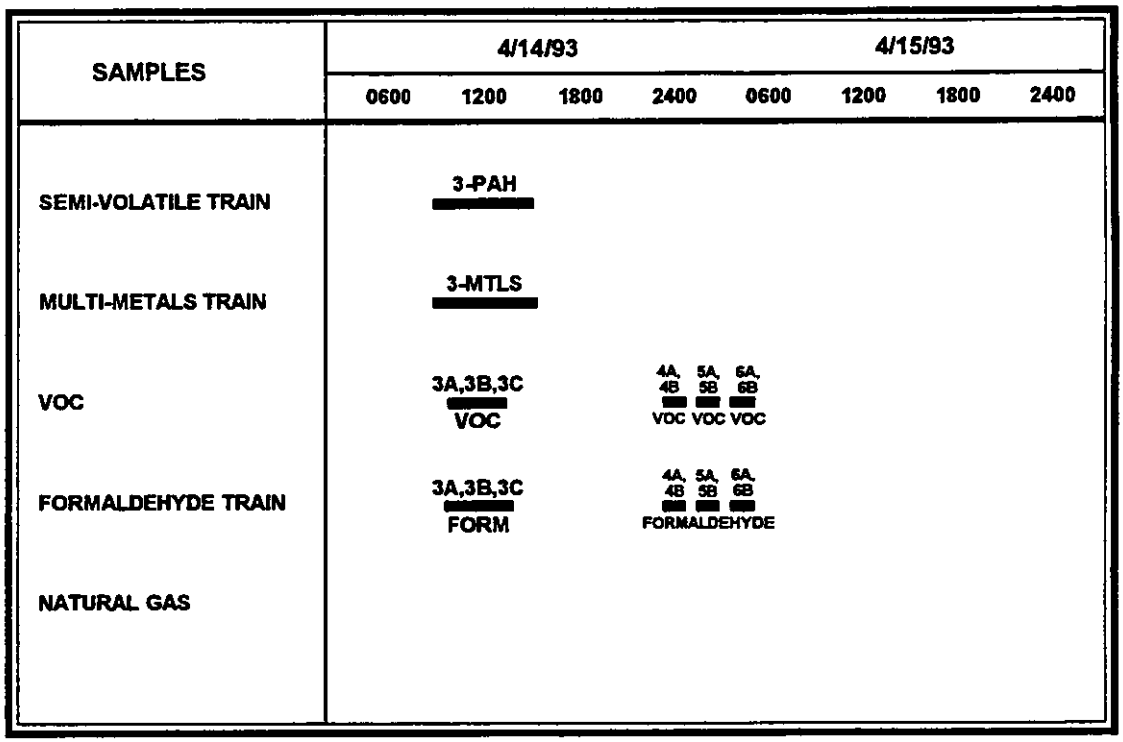
KEY:

- ● DENOTES SAMPLE TIMES FOR ON-LINE FUEL F-FACTOR ANALYSIS
- ▬ CONTINUOUS SAMPLING
- 1 INDICATES RUN NUMBER

NOTES:

NATURAL GAS SAMPLE TIMES INDICATE ON-LINE FUEL F-FACTOR ANALYSIS
(SAMPLING TIMES FOR OTHER FRACTIONS NOT SUPPLIED BY IGT)
METALS RUN 2 VOID
PCB ANALYZED FROM PAH TRAIN

Figure 3-1. Sampling Schedule for Site 121



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KEY:

- ● DENOTES GRAB SAMPLE TIMES
- ▬ CONTINUOUS SAMPLING
- 1 INDICATES RUN NUMBER

NOTES:

PAH ANALYZED FROM PAH TRAIN
RUNS 4, 5 AND 6 WERE UNIT OPERATION TESTS:
RUN 4: MINIMUM LOAD, NORMAL O_2
RUN 5: MINIMUM LOAD, LOW O_2
RUN 6: MINIMUM LOAD, HIGH O_2

Figure 3-1. Sampling Schedule for Site 121 (continued)

is equal to or greater than 50% of the uncorrected measurement, the concentration is flagged with a "B." When the blank correction results in a value less than the reporting limit, the concentration is presented as detected at the reporting limit. Generally, field blank analyses are used to provide information on sample collection conditions but not to correct the results. For this program, field blanks were not corrected from any sample results; however, they are presented for comparison with metals emissions. When the field blank is equal to or greater than 50% of the uncorrected measurement, the concentration is flagged with an "F." Laboratory blanks or reagent blanks were subtracted from results for some metals. Appendix H presents blank correction data and an example of how the blank correction contribution is calculated.

3.2.2 Average Concentrations

The following criteria were used to average data from the individual runs.

- When all values are above the reporting limit, the mean arithmetic concentration is calculated using the reported quantities.

- For results that include values both above and below the reporting limit, one-half of the reporting limit is used for values below the reporting limit to calculate the mean. For example:

Analytical Values	Calculation	Mean Value
10,12,ND(8)	(10+12+[8/2])/3	8.7

By our convention, the calculated mean cannot be smaller that the largest reporting limit value. In the following example, the calculated mean is 2.8. This is less than the largest reporting limit, so the reported mean becomes ND(4).

Analytical Values	Mean Value
5,ND(4), ND(3)	ND(4)

- When all analytical results are less then the reporting limit, the presented value is the largest reporting limit value expressed as "ND (the largest reporting limit value)."

3.2.3 Summation of Multiple Train Fractions

Some sample trains, such as mercury in the metals train, are analyzed in multiple fractions. If all fractions were detected, the total emissions were reported as the sum of the measurements. If all fractions were not detected, total emissions were reported as not detected, less than the sum of the reporting limits of the fractions. If one or more, but not all fractions were not detected, the total is reported as the sum of the detected values and one-half of the reporting limit for the non-detected values.

3.2.4 Method Detection Limit and Reporting Limit

The method detection limit (MDL) is defined by 40 CFR 136, Appendix B - Definition and Procedure for the Determination of the Method Detection Limit - Revision 1. It states, "The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte." The MDL is determined by seven replicate analyses of an analyte in a given matrix at one to five times the estimated MDL. It is calculated as:

$$MDL = 3.143\ S$$

where:

S is the standard deviation of the replicate analyses, and

3.143 is the student "t" value corresponding to seven replicates with n-1 degrees of freedom at the 99% confidence level.

Additional criteria are imposed by the procedure for calculating subsequent method detection limits. In practice, the method detection limit can be impacted by variability in performing the analytical procedure, the sample matrix and the analyte concentration of the sample. Because the method detection limit may not completely specify the confidence an analytical laboratory has in reporting a result, a laboratory typically presents a reporting limit or quantitation limit. The numerical difference between the method detection limit as defined by the CFR and a laboratory's reporting limit varies for different types of analyses and sample matrices but generally varies from the MDL value to approximately three times greater than the MDL. The values presented in this report are all based on individual laboratories' stated reporting limits. Both the detection and the reporting limit are indicated by "ND" in this report.

3.2.5 Assignment of Bias and Uncertainty Estimates

In calculating the uncertainties that are presented in this report, procedures were followed that have been previously established for FCEM data treatment. This procedure involved calculating an overall uncertainty for each result using standard statistical techniques and known measurement biases. An error propagation analysis was performed on calculated results to determine the contribution of process, sampling and analytical variability, and measurement bias, to the overall uncertainty in the result.

Example calculations and bias and uncertainty estimates are presented in Appendix F.

3.3 NATURAL GAS

This section presents the analytical results for natural gas samples. Natural gas sampling and analysis was performed by IGT Analytical. Natural gas sampling was performed on April 13, 1993, during Run 2.

IGT conducted triplicate on-line measurements of natural gas composition (major and minor components) and higher heating value (HHV) for EPA Method 19 F-factor calculations. In addition to the triplicate composition and HHV analyses, IGT also collected several sample types for trace species analysis. These sample types included a whole gas sample, cryogenic sample trap condensate, a lean gas sample, particulate, pipeline condensate, sorbent tubes and pipeline deposits. These various samples were analyzed for trace species, including metals, oxygenated compounds, nitrogen compounds, halocarbons, sulfur compounds and radon. Analysis for trace species was only conducted once on these various sample types.

Laboratory methods of analysis for many trace species have not been established for natural gas, so IGT has developed a number of internal analysis methods. Samples were screened initially by GC/MS to determine which species were present, and then analyzed for those species using the procedures listed in Appendix A.

Table 3-1 presents the natural gas analysis results for Site 121. Complete results are presented in Appendix B. As noted above, composition and higher heating value determinations were performed in triplicate, while trace species values reflect a single analysis. For those components determined using triplicate on-line analysis, an uncertainty at the 95% confidence interval is also shown in Table 3-1. The confidence interval is the range about the mean in which the true mean lies within a given probability. For instance, it is 95% certain that the true mean ethane value in the natural gas is between 1.66 and 1.70 mole percent.

3.4 FLUE GAS

Table 3-2 summarizes the concentration of the species in the flue gas emitted from the boiler. Additional data are presented in Appendix B. For the metals results, the probe and nozzle rinse, filter and nitric acid/hydrogen peroxide impinger catch were all combined before analysis; therefore, the data represent the total (particulate plus vapor phase) metal concentration in the flue gas. The separate fractions were combined to lower the reporting limits. Mercury results were obtained by analyzing the permanganate impinger solution and an aliquot from the front half and nitric acid/hydrogen peroxide impinger solution. These results were added together to provide the total mercury concentration.

Metals run 2 was invalidated because the concentrations of chromium, copper and nickel indicated field contamination at 750, 940 and 410 μg/train, respectively. The entire run was invalidated since the results of these three trace metals indicated contamination of the sample.

The total concentrations from the two remaining runs were averaged according to the convention outlined previously to obtain an overall mean concentration and the uncertainty at the 95% confidence interval. Appendix F contains detailed descriptions of bias estimates and uncertainty calculations.

3.5 EMISSION FACTORS

Table 3-3 presents mean emission factors, expressed as lb/10^{12} Btu, for Site 121.

The metals with the highest emission factors were barium, copper, molybdenum and phosphorus at 5.7, 1.2, 1.9 and 4.6 lb/10^{12} Btu, respectively. Emission factors for the other metals ranged from 0.01-1.19 lb/10^{12} Btu.

Of the PAH target species, only naphthalene, phenanthrene and 2-methylnaphthalene were detected. Their emission levels ranged from 0.016-1.13 lb/10^{12} Btu. Other PAH species were not detected in the range of 0.003-0.028 lb/10^{12} Btu. None of the PCB isomer groups were detected at levels ranging from 0.001-0.055 lb/10^{12} Btu.

Toluene had the highest emission value of the volatile organic species at 13.3 lb/10^{12} Btu. Benzene emissions levels were 1.38 lb/10^{12} Btu, and formaldehyde emission levels were 5.9 lb/10^{12} Btu.

TABLE 3-1
NATURAL GAS ANALYSIS FOR SITE 121

Parameter	Mean	Uncertainty at 95% C.I.
Fuel Flow Rate (Baseline), kscfhr at 68°F	3,072	9.0
Moisture, ppm	55	NC
Oxygen, ppm	5.0	NC
Helium, mole%	0.023	0.004
Hydrogen, mole%	0.002	0.001
Nitrogen, mole%	0.49	0.08
Carbon Dioxide, mole%	1.76	0.02
HHV, Btu/scf at 68°F	998	1.4
Hydrocarbons, mole% (1)		
Methane	95.5	0.1
Ethane	1.68	0.02
Propane	0.351	0.007
i-Butane	0.038	0.0
n-Butane	0.055	0.004
neo-Pentane	0.001@	NC
i-Pentane	0.02	0.0
n-Pentane	0.02	0.0
C6 & Heavier	0.032	0.004
Aliphatics, ppm		
Cyclopentane	6	NC
Hexanes	142	NC
Methyl cyclopentane	19	NC
Cyclohexane	26	NC
Heptanes	59	NC
Methyl cyclohexane	27	NC
Octanes	26	NC
Nonanes	13	NC
Decanes	4.1	NC
Undecanes	1.2	NC
Dodecanes	0.8	NC
Tridecanes	0.6	NC
Tetradecanes	0.40@	NC

ND( ) - species not detected at the reporting limit. (continued)

@ - species detected at less than five times the reporting limit.

NC - Not calculated; only one analysis performed for this species.

Notes:

(1) Results (with the exception of neopentane) from triplicate on-line fuel composition analyses performed on-site.

(2) Only a qualitative or semi-quantitative anaylsis can be performed on these elements.

(3) Other metals include: antimony, germanium, iron, silicon, and tin.

TABLE 3-1 (continued)
NATURAL GAS ANALYSIS FOR SITE 121

Parameter	Mean	Uncertainty at 95% C.I.
Aromatics, ppm		
Benzene	7	NC
Toluene	6	NC
Ethylbenzene	0.5	NC
Xylenes	3.2	NC
C3-benzenes	0.1	NC
Naphthalenes	ND(0.1)	NC
PAHs	ND(0.02)	NC
Sulfur Compounds, ppm		
Hydrogen sulfide	ND(0.02)	NC
Carbonyl sulfide	ND(0.02)	NC
Carbon disulfide	ND(0.02)	NC
Methyl mercaptan	ND(0.02)	NC
Ethyl mercaptan	ND(0.02)	NC
i-Propyl mercaptan	0.02@	NC
n-Propyl mercaptan	ND(0.02)	NC
t-Butyl mercaptan	ND(0.02)	NC
Dimethyl sulfide	ND(0.02)	NC
Methyl ethyl sulfide	ND(0.02)	NC
Diethyl sulfide	ND(0.02)	NC
Methyl ethyl disulfide	ND(0.02)	NC
Diethyl disulfide	ND(0.02)	NC
Methyl i-propyl disulfide	ND(0.02)	NC
Ethyl i-propyl disulfide	ND(0.02)	NC
Ethyl n-propyl disulfide	ND(0.02)	NC
i-Propyl n-propyl disulfide	ND(0.02)	NC
Di-i-propyl disulfide	ND(0.02)	NC
i-Propyl t-butyl disulfide	ND(0.02)	NC
Ethyl t-butyl disulfide	ND(0.02)	NC
Di-t-butyl disulfide	ND(0.02)	NC
Thiophane	0.03@	NC
Other target compounds	ND(0.02)	NC
Halocarbons, ppm		
35 target compounds	ND(0.1)	NC
PCB	ND(0.01)	NC

ND( ) - species not detected at the reporting limit.
@ - species detected at less than five times the reporting limit.
NC - Not calculated; only one analysis performed for this species.
Notes:
(1) Results (with the exception of neopentane) from triplicate on-line fuel composition analyses performed on-site.
(2) Only a qualitative or semi-quantitative anaylsis can be performed on these elements.
(3) Other metals include: antimony, germanium, iron, silicon, and tin.

(continued)

TABLE 3-1 (continued)
NATURAL GAS ANALYSIS FOR SITE 121

Parameter	Mean	Uncertainty at 95% C.I.
Nitrogen Compounds, ppm		
Ammonia	ND(4)	NC
17 target compounds	ND(0.5)	NC
Oxygenated Compounds, ppm		
Methanol	21	NC
Acetaldehyde	ND(1)	NC
Acetone	ND(1)	NC
Other 14 target compounds	ND(1)	NC
Elements/Compounds		
Total Arsenic, μg/m3	4@	NC
Total Mercury, μg/m3	0.02@	NC
NO, ppm	ND(0.1)	NC
NOx, ppm	1.2	NC
Radon, pCi/L	1@	NC
Metals and Anion Precursors, ppm		
Cobalt (2)	ND(0.1)	NC
Copper (2)	ND(0.05)	NC
Lead (2)	ND(0.1)	NC
Nickel	ND(0.05)	NC
Selenium	ND(0.002)	NC
Phosphorus	ND(0.01)	NC
Chlorine	ND(0.2)	NC
Fluorine	ND(1)	NC
Bromine	ND(0.1)	NC
Other metals (3)	ND	NC

ND( ) - species not detected at the reporting limit.
@ - species detected at less than five times the reporting limit.
NC - Not calculated; only one analysis performed for this species.
Notes:
(1) Results (with the exception of neopentane) from triplicate on-line fuel composition analyses performed on-site.
(2) Only a qualitative or semi-quantitative anaylsis can be performed on these elements.
(3) Other metals include: antimony, germanium, iron, silicon, and tin.

TABLE 3-2
STACK GAS COMPOSITION DATA AT SITE 121

Substance/Stream	Run 1	Run 2	Run 3	Average	Field Blank[1]	95% C.I.
Gas Stream Flow Rates,						
dscfm	623,012	620,502	646,093	629,869		35,020
Nm^3/Hr	986,338	982,364	1,022,879	997,194		55,443
Metals, ug/Nm^3						
Arsenic	0.24F	NR	0.31F	0.27F	0.18	0.42
Barium	9.7	NR	6.1	7.9	0.98	23.1
Beryllium	ND(0.02)	NR	ND(0.01)	ND(0.02)	ND(0.01)	NC
Cadmium	0.11@	NR	ND(0.04)	0.06	ND(0.04)	0.50
Chromium	2.1	NR	0.90	1.5	0.31	7.7
Cobalt	ND(0.15)	NR	ND(0.15)	ND(0.15)	ND(0.15)	NC
Copper	2.1	NR	1.2	1.6	0.09	5.9
Lead	0.81@F	NR	0.79@F	0.80@F	0.80	0.16
Manganese	0.68F	NR	0.54@F	0.61F	0.58	0.86
Mercury	ND(0.42)	NR	ND(0.54)	ND(0.54)	0.34	NC
Molybdenum	2.7F	NR	2.5F	2.6F	2.5	1.4
Nickel	2.1	NR	1.2@	1.6	0.45	5.8
Selenium	ND(0.04)	NR	ND(0.04)	ND(0.04)	ND(0.04)	NC
Phosphorous	5.9F	NR	6.8F	6.3F	6.4	5.5
Vanadium	0.71	NR	0.57	0.64	0.27	1.14

ND( ) - Not detected at less than the reporting limit.
NR - Not reported.
NC - Not calculated.
@ - Concentration is less than five times the reporting limit.
B - Blank correction exceeded 50% of uncorrected result.
F - Field blank exceeded 50% of uncorrected result.
Note: Metals run 2 not used in average due to probable field contamination of sample. Data included in Appendix C.
(1) Field blank levels for metals only.

(continued)

TABLE 3-2 (continued)
STACK GAS COMPOSITION DATA AT SITE 121

Substance/Stream	Run 1	Run 2	Run 3	Average	Uncertainty at 95% C.I.
PCBs, ug/Nm³					
total Chlorobiphenyls	ND(0.008)	ND(0.004)	ND(0.003)	ND(0.008)	NC
total Dichlorobiphenyls	ND(0.005)	ND(0.003)	ND(0.001)	ND(0.005)	NC
total Trichlorobiphenyls	ND(0.078)	ND(0.007)	ND(0.002)	ND(0.078)	NC
total Tetrachlorobiphenyls	ND(0.002)	ND(0.001)	ND(0.002)	ND(0.002)	NC
total Pentachlorobiphenyls	ND(0.005)	ND(0.004)	ND(0.004)	ND(0.005)	NC
total Hexachlorobiphenyls	ND(0.001)	ND(0.001)	ND(0.001)	ND(0.001)	NC
total Heptachlorobiphenyls	ND(0.002)	ND(0.002)	ND(0.002)	ND(0.002)	NC
total Octachlorobiphenyls	ND(0.001)	ND(0.001)	ND(0.001)	ND(0.001)	NC
total Nonachlorobiphenyls	ND(0.001)	ND(0.001)	ND(0.001)	ND(0.001)	NC
Decachlorobiphenyl	ND(0.004)	ND(0.003)	ND(0.002)	ND(0.004)	NC
PAHs, ug/Nm³					
Naphthalene	1.20F	2.22F	1.36F	1.59F	1.38
Phenanthrene	0.054	ND(0.015)	ND(0.010)	0.022	0.068
2-Methylnaphthalene	0.071	0.078	0.028	0.059	0.067
VOC, ug/Nm³	Run 3A	Run 3B	Run 3C		
Benzene	2.9	1.5@	1.3@	1.9	2.1
Toluene	NR	18.4	17.8	18.1	3.7
Formaldehyde	7.0F	9.1F	7.8	8.0F	2.6

ND( ) - Not detected at less than the reporting limit.
NR - Not reported; sample appears to have been contaminated in field by solvents.
NC - Not calculated.
@ - Concentration is less than five times the reporting limit.
B - Blank correction exceeded 50% of uncorrected result.
F - Field blank exceeded 50% of uncorrected result.
Notes:
VOC Runs 3A, 3B, and 3C performed during Run 3. Toluene Run 3A not used in average, and data included in Appendix C.

TABLE 3-3
STACK GAS EMISSION FACTORS AT SITE 121

Gas Flow, dscfm	629,869	
Fuel Flow Rate, kscfhr at 68°F	3,072	
HHV, Btu/scf at 68°F	998	
Substance	lb/10^{12} Btu	Uncertainty at 95% C.I.
Metals		
Arsenic	0.20F	0.31
Barium	5.7	16.5
Beryllium	ND(0.01)	NC
Cadmium	0.05	0.42
Chromium	1.08	5.5
Cobalt	ND(0.11)	NC
Copper	1.2	4.4
Lead	0.58F	0.094
Manganese	0.44F	0.60
Mercury	ND(0.40)	NC
Molybdenum	1.9F	1.0
Nickel	1.2	4.2
Selenium	ND(0.03)	NC
Phosphorus	4.6F	4.4
Vanadium	0.46	0.62
PAHs		
Naphthalene	1.13F	0.98
Phenanthrene	0.016	0.050
2-Methylnaphthalene	0.042	0.048
PCBs		
total Chlorobiphenyls	ND(0.005)	NC
total Dichlorobiphenyls	ND(0.004)	NC
total Trichlorobiphenyls	ND(0.055)	NC
total Tetrachlorobiphenyls	ND(0.001)	NC
total Pentachlorobiphenyls	ND(0.004)	NC
total Hexachlorobiphenyls	ND(0.001)	NC
total Heptachlorobiphenyls	ND(0.001)	NC
total Octachlorobiphenyls	ND(0.001)	NC
total Nonachlorobiphenyls	ND(0.001)	NC
Decachlorobiphenyl	ND(0.003)	NC
VOC		
Benzene	1.38	1.56
Toluene	13.3	2.7
Formaldehyde	5.9F	1.9

ND( ) - Not detected at less than the reporting limit.
F - Field blank exceeded 50% of average uncorrected result.

SECTION 4.0

UNIT OPERATION AND VOC EMISSIONS

This section summarizes the data collected at Site 121 during tests conducted to determine the effect of unit operation (load and excess air) on benzene, toluene and formaldehyde emissions. Unit operation during these additional tests (Tests 4, 5 and 6) was discussed in Section 2.3, and the sampling schedule was included in Section 3.1. As with the results from the base test program, sampling, preparation and analytical methods are summarized in Appendix A. Detailed analytical data can be found in Appendices B and C, sampling data are located in Appendix D and quality assurance measurements are summarized in Appendices G and H.

4.1 TEST OVERVIEW

In order to determine if emissions of volatile organic compounds are impacted by operating changes that impact the combustion process, tests were performed at minimum load with three levels of excess air (normal, low and high). Minimum load was selected as the alternate test condition since it is a common operating condition for utility boilers, and because it produces the lowest flame and furnace temperatures that would normally be observed in the boiler. Excess air level was chosen as the variable to be changed for the minimum load tests. It is commonly controlled to minimize NO_x emissions from utility boilers. Varying excess air levels or other parameters that impact NO_x emissions at full load at Site 121 were not possible due to strict NO_x emission limits for the boiler.

Minimum load for these tests was 123 MW gross (37% of full load). Air preheater inlet O_2 levels were 3.75, 2.69 and 5.66% for normal, low and high O_2 level tests, respectively. Unit operating data were collected once for each test condition. Detailed unit operating data are presented in Appendix E.

4.2 FLUE GAS

Table 4-1 presents the stack gas concentrations of benzene, toluene and formaldehyde for the three minimum load tests. For reference, the concentrations for VOCs during the base test program at full load are also included.

The total concentrations from each run were averaged according to the convention outlined previously to obtain an overall mean concentration and the uncertainty at the 95%

confidence interval. Appendix F contains detailed descriptions of bias estimates and uncertainty calculations.

TABLE 4-1
STACK GAS VOC DATA AT SITE 121

Substance/Stream				Average	Uncertainty at 95% C.I.
VOC, ug/Nm$_3$					
Full Load, Normal O_2 (334 MW, 2.85% O_2)	Run 3A	Run 3B	Run 3C		
Benzene	2.9	1.5@	1.3@	1.9	2.1
Toluene	NR	18.4	17.8	18.1	3.7
Formaldehyde	7.0F	9.1F	7.8	8.0F	2.6
Minimum Load, Normal O_2 (123 MW, 3.75% O_2)	Run 4A	Run 4B			
Benzene	1.0@	1.7@		1.3@	4.1
Toluene	3.2	3.8		3.5	3.4
Formaldehyde	7.2	6.7		7.0	3.3
Minimum Load, Low O_2 (123 MW, 2.69% O_2)	Run 5A	Run 5B			
Benzene	0.8@	1.1@		1.0@	2.5
Toluene	1.6@	3.2		2.4	10.0
Formaldehyde	6.3F	6.1F		6.2F	1.4
Minimum Load, High O_2 (122 MW, 5.66% O_2)	Run 6A	Run 6B			
Benzene	1.6@	NA		1.6@	NC
Toluene	3.2	NA		3.2	NC
Formaldehyde	5.8	10.4		8.1	29.6

Notes:
@ Concentration is less than five times the reporting limit.
F - Field blank exceeded 50% of uncorrected result.
NR - Not reported; sample appears to have been contaminated in field by solvents.
NC - Not calculated; only one run available.
NA - Not analyzed; Tedlar bag arrived at laboratory flat and was not analyzed.
Runs 3A, 3B and 3C performed during Run 3. Run 3A toluene result invalidated.
Runs 4A and 4B performed during Run 4.
Runs 5A and 5B performed during Run 5.
Runs 6A and 6B performed during Run 6.

SECTION 5.0

DATA EVALUATION

Several procedures can be used to evaluate the information developed during a field sampling program. In the case of Site 121, three methods were used to evaluate data quality. First, the process operation data were examined to determine if the unit operated at normal, steady-state conditions during the sampling periods. Second, the QA/QC protocol for sampling and analytical procedures used at Site 121 (i.e., equipment calibration and leak checks, duplicates, blanks, spikes, standards, etc.) was evaluated. Site 121 QA/QC date were compared with FCEM project objectives. Data quality was evaluated using QA/QC measurements that assess bias, accuracy and precision, such as blank measurement, matrix spike recoveries, surrogate recoveries, replicate runs and laboratory control duplicates. Third, trace metal material balances were calculated around the boiler. Material balances involve the summation and comparison of mass flow rates in several streams often sampled and analyzed by different methods. Closure of material balance within an acceptable range can be used as an indicator of accurate results for the fuel and the boiler outlet stream.

5.1 PROCESS OPERATION

Process operating data were examined to ensure that operation was stable during sampling periods. Measurements were taken from control room instrumentation. Boiler operating data were collected several times during each test. Table 5-1 shows the key unit operating parameters and conditions for the base test program. The coefficient of variation (CV), defined as the standard deviation of the measurements divided by the mean of the measurements, was calculated for each parameter to evaluate process variability over the three days of testing.

Steady boiler operation was maintained during the base test program, as indicated by the low CVs for load, fuel flow, steam flow and boiler oxygen levels.

5.2 SAMPLE COLLECTION

Several factors indicate the acceptable collection of gas samples. Key components of the sampling equipment—pitot tubes, thermocouples, dry gas meters, and sampling nozzles—were calibrated before use in the field. Dry gas meter calibrations were checked at the end of sampling. These and additional periodic equipment calibrations are on file at Carnot. The methods used to collect metals, PAH and PCB, and volatile organic compounds were comparable to those used at other FCEM sites. All sampling runs were well-documented, and isokinetic flue

TABLE 5-1
SUMMARY OF UNIT OPERATION
SITE 121

Date	4/12/93	4/13/93	4/14/93	Mean	CV[1]
Unit Load, MW gross	333.6	334.0	334.2	333.9	0.1%
Air Flow, %	97	96	97	97	0.6%
Fuel Gas Flow, kscfh at 60°F	3,022	3,025	3,029	3,025	0.1%
Steam flow, kpph	2,000	2,000	2,000	2,000	0%
O_2, % A/B (economizer outlet)	2.7/1.9	2.5/1.9	2.7/2.2	2.6/2.0	4%/9%
Opacity, %	<2	<2	<2	<2	0%

(1) The coefficient of variation (CV) is the standard deviation divided by the mean.

gas samples for the base test program were collected at rates between 95 and 105% isokinetic. Typical flue gas conditions at full load were 6.28% oxygen, 15.1% moisture, 271°F and flow rates of approximately 630,000 dscfm. The values are typical of a natural gas-fired utility boiler of this size and design.

Sufficient data were collected using standard sampling and analysis methods to ensure acceptable data completeness and the comparability of measurements for PAHs, PCBs and VOCs. However, one of the three metals runs conducted was invalidated, so the completeness objective for metals sampling was not met. Major differences from other FCEM programs were that benzene and toluene samples were collected according to CARB Method 410A in Tedlar bags and formaldehyde samples were collected non-isokinetically according to CARB Method 430 in midget impingers containing 2,4-dinitrophenylhydrazine.

Flue gas exiting the stack was sampled using four horizontal sample ports on the stack. A total of 24 points were sampled for each isokinetic test. The plane of the sample ports was 2.6 stack diameters downstream of the stack breachings and 6.2 stack diameters from the top of the stack, thus meeting EPA Method 1 requirements for minimum distances from flow disturbances.

Natural gas samples are considered to be representative of the gas fired during the flue gas sampling. Each natural gas sample analyzed for F-factor calculations was a grab sample collected at three times spanning one of the baseline testing days.

Calculated exhaust gas flow rates were used for this site. The flow rates are calculated using natural gas usage and fuel F-factor as follows:

Flow rate (dscfm) = fuel usage (scf/hr @ 68°F) x HHV (Btu/scf @ 68°F) x F-factor (dscf/MMBtu @ 0% O_2) x MMBtu/10^6 Btu x 1 hr/60 min x (20.9/(20.9 - %O_2))

where: HHV = 998 Btu/scf @ 68°F, and
F-factor = 8,618 dscf/MMBtu @ 0% O_2.

This calculation was used to determine exhaust gas flow rates because it was subject to less uncertainty than the flow rates determined by S-type pitot traverse measurements. The natural gas fuel usage was determined from control room instrumentation. On average, the stack pitot traverse flow rate results were 6.5% higher than the F-factor flow rates.

Details on sample collection are contained in Appendix A (sampling and analytical summary). Process stream flow rates and conditions during testing are presented in Appendix D.

5.3 EVALUATION OF MEASUREMENT DATA QUALITY

An evaluation of the quality of the measurement data is based on quality control data obtained experimentally during sampling and analysis. Generally, the type of quality control information obtained that pertains to measurement precision, accuracy, and blank effects, is determined using various types of replicate, spiked, and blank samples. The specific characteristics evaluated depend on the type of quality control checks performed. For example, blanks may be prepared at different stages in the sampling and analysis process to isolate the source of a blank effect. Similarly, replicate samples may be generated at different stages to isolate and measure sources of variability. The QA/QC measures commonly used as part of the FCEM data assessment protocol, and the characteristic information obtained, are summarized in Table 5-2. The absence of any of these types of quality control checks from the data reports does not necessarily reflect poorly on the quality of the data, but does limit the ability to measure the various components of measurement error.

As shown in the table, different QC checks provide different types of information pertaining to the sources of inaccuracy, imprecision, or blank effects. As part of the FCEM project, measurement precision and accuracy are typically estimated from QC indicators that cover as much of the total sampling and analytical process as feasible. Precision and accuracy measurements are based primarily on the actual sample matrix. The precision and accuracy estimates obtained experimentally during the test programs are compared with data quality objectives (DQOs) established for the FCEM project.

These DQOs are not intended to be used as validation criteria, but they can be used as empirical estimates of the precision and accuracy that are expected from existing reference measurement methods. Although analytical precision and accuracy are relatively easy to quantify and control, sampling precision and accuracy are unique to each site and each sample matrix. Data that do not meet these objectives are not necessarily unacceptable. Rather, the intent is to document the precision and accuracy actually obtained; the objectives serve as benchmarks for comparison. The effects of not meeting the objectives should be considered in light of the intended use of the data.

5.4 ANALYTICAL QUALITY CONTROL RESULTS

Table 5-3 summarizes the types of quality control data reported for Site 121. The results of these analyses are summarized in Appendices G and H. Table 5-4 presents a summary of precision and accuracy measurements. Accuracy as used in this table reflects laboratory recovery and does not reflect the accuracy of the sampling procedure.

Based on the quality control data evaluated, the majority of the results met the project objectives.

The following potential problems were highlighted by the quality control data:

TABLE 5-2
TYPES OF QUALITY CONTROL SAMPLES

QC Activity	Characteristic Measured
Precision	
Replicate samples collected over time under the same conditions	Total variability, including process or temporal, sampling and analytical.
Duplicate field samples collected simultaneously	Sampling plus analytical variability at the actual sample concentrations.
Duplicate analyses of a single sample	Analytical variability at the actual sample concentrations.
Matrix- or media-spiked duplicates	Sampling plus analytical variability at an established concentration.
Laboratory control sample duplicates	Analytical variability in the absence of sample matrix effects
Surrogate-spiked sample sets	Analytical variability in the sample matrix but at an established concentration.
Accuracy	
Matrix-spiked samples	Analyte recovery in the sample matrix, indicating possible matrix interferences and other effects. In a single sample, includes both random error (imprecision) and systematic error (bias)
Media-spiked samples	Same as matrix-spiked samples. Used where a matrix-spiked sample is not feasible, such as certain stack sampling methods.
Surrogate-spiked samples	Analyte recovery in the sample matrix, to the extent that the surrogate compounds are chemically similar to the compounds of interest. Primarily used as an indicator of analytical efficacy.
Laboratory control standards (LCS)	Analyte recovery in the absence of actual sample matrix effects. Used as an indicator of analytical control.
Standard Reference Material	Analyte recovery in a matrix similar to the actual samples
Blank Effects	
Field Blank	Total sampling plus analytical blank effect, including sampling equipment and reagents, sample transport and storage, and analytical reagents and equipment.
Trip Blank	Blank effects arising from sample transport and storage. Typically used only for volatile organic compound analyses.
Method Blank	Blank effects inherent in analytical method, including laboratory reagents and equipment.
Reagent Blank or Field Reagent Blank	Blank effects from reagents used during sampling and analysis.

TABLE 5-3
TYPES OF QUALITY CONTROL DATA REPORTED
SITE 121

	Precision					Accuracy				Blank			
Analysis	Replicate Runs	Duplicate Field Samples	Duplicate Laboratory Analysis	Matrix or Media Spiked Duplicate	Laboratory Control Sample Duplicate	Matrix or Media Spike	Surrogate Spike	Laboratory Control Sample	Standard Reference Material	Field Blank	Trip Blank	Laboratory Method Blank	Reagent Blank (Field)
Exhaust Gas													
Metals	✓		✓		✓	✓		✓		✓		✓	✓
Polycyclic Aromatic Hydrocarbons	✓		✓	✓		✓	✓			✓		✓	
Polychlorinated Biphenyls	✓		✓	✓		✓	✓			✓		✓	
Volatile Organic Compounds	✓		✓										✓
Formaldehyde	✓		✓	✓		✓				✓	✓	✓	
Natural Gas													
Major and Minor Components	✓		✓						✓				

- There is a concern with the determination of arsenic in the exhaust gas samples. Precision of duplicate analyses was 61% RPD. Because the arsenic concentrations were low, blank levels were significant compared to the sample values. Laboratory blank corrections were 22% of the uncorrected value. Field blank levels were 73% of the uncorrected sample values.

- Metals run 2 was invalidated because the concentrations of chromium, cooper and nickel indicated field contamination at 750, 940 and 410 μg/train, respectively. The entire run was invalidated because it was assumed that if the results of these three common metals indicated contamination, the remaining metals could potentially be contaminated.

- The emissions of most metals were expected to be low from this source. Because of the low levels relative to the reagents used in the analysis procedure, blank effects impact the interpretation of the data. Field blank levels were greater than 50% of uncorrected sample values for arsenic, lead, manganese, molybdenum and phosphorus. The only metals results where field blanks levels do not significantly affect the interpretation of emission values are barium, chromium, copper, nickel and vanadium.

- The results of the toluene analysis from VOC run 3A were not included in the average result. This sample contained 250 $\mu g/Nm_3$ of toluene compared to an average of 18 $\mu g/Nm_3$ for runs 3B and 3C. Contamination of sample 3A was considered likely.

- Naphthalene field blank levels were 143% of the uncorrected sample values. Naphthalene is a suspected degradation product of a common contaminant in the XAD-2 resin used in the PAH sampling train (Thomson, R.D., Foster, M.G., "Degradation of XAD-2 Resin In Dry Storage and Its Impact on PAH Analysis," AWMA, 1991).

- Formaldehyde results may be biased high as indicated by field blank levels. Three of six field blanks were higher than the sample values. Individual field blanks ranged from 39-60% of the uncorrected sample values. Although the precise extent of this bias cannot be assessed, it can be indicated by the field and trip spikes which, although they were within the method specification of 60-140%, had recoveries of 140 and 131%, respectively.

- The accuracy of benzene and toluene analysis was not assessed by matrix spike recovery for this test series.

Definition of Quality Assurance Terms

Presented below is a general discussion of considerations to be used when evaluating data and definitions of terms used to describe quality assurance indicators.

Precision is a measure of the reproducibility of laboratory analyses of the same sample. It is expressed in terms of distribution or scatter of the data, and traditionally calculated as the standard deviation or coefficient of variation (CV, standard deviation divided by the mean). For duplicate analysis, precision is expressed as the relative percent difference (RPD).

$$RPD = \frac{x_1 - x_2}{\bar{x}} \times 100$$

Accuracy is a measure of the degree of conformity of a value generated by a specific procedure to the assumed or accepted true value; it includes both precision and bias. Bias is the persistent positive or negative deviation of the method average value from the assumed or accepted true value.

The efficacy of the analytical procedure for a given sample matrix is quantified by the analysis of spiked samples containing target or indicator analytes or other quality assurance measures, as necessary. However, all spikes, unless made to the flowing stream ahead of the sampling, produce only estimates of recovery of the analyte through all of the measurement steps occurring after the addition of the spike. A good spike recovery tells little about the true value of the sample before spiking.

Representativeness expresses the degree to which sampling data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. The representativeness criterion is based on making certain that sampling locations are properly selected and that a sufficient number of samples are collected.

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. Sampling data should be comparable with other measurement data for similar samples collected under similar conditions. This goal is achieved using standard techniques to collect and analyze representative samples and by reporting analytical results in appropriate units. Data sets can be compared with confidence when the precision and accuracy are known.

Completeness is an expression of the number of valid measurements obtained compared with the number planned for a given study. The goal is to generate a sufficient amount of valid data.

A discussion of the overall measurement precision, accuracy, and blank effects is presented below for each measurement type. Complete QA/QC data are presented in Appendix G. Appendix H presents analytical and blank correction data. Table H-6 contains a summary of blank correction contributions to the sample values.

TABLE 5-4
SUMMARY OF PRECISION AND ACCURACY ESTIMATES
Site 121

Measured Parameter	How Measured	Objectives		Measured	
		Precision	Accuracy	Precision	Accuracy
Metals in Exhaust Gas	Precision - Duplicate Analysis Accuracy - Spiked Samples				
Arsenic		10% RPD	75-125%	61% RPD	92%
Barium		10% RPD	75-125%	0.7% RPD	86%
Beryllium		10% RPD	75-125%	NC	81%
Cadmium		10% RPD	75-125%	NC	81%
Chromium		10% RPD	75-125%	1.2% RPD	78%
Cobalt		10% RPD	75-125%	NC	75%
Copper		10% RPD	75-125%	2.6% RPD	81%
Lead		10% RPD	75-125%	NC	MSA
Manganese		10% RPD	75-125%	2.0% RPD	79%
Mercury		10% RPD	75-125%	13% RPD	101%
Molybdenum		10% RPD	75-125%	2.0% RPD	78%
Nickel		10% RPD	75-125%	26% RPD	70%
Selenium		10% RPD	75-125%	NC	91%
Phosphorus		10% RPD	75-125%	8.2% RPD	84%
Vanadium		10% RPD	75-125%	5.7% RPD	81%
PAH in Exhaust Gas (detected species)	Precision - Matrix Spike Duplicate Accuracy - Pre-extraction Surrogate Spikes				
Napthalene		50% RPD	50-150%	77% RPD	59%
Phenanthrene		50% RPD	50-150%	4.4% RPD	96%
2-Methylnaphthalene		50% RPD	50-150%	NP	NA

Precision for metals was measured as duplicate analyses and replicate runs. Replicate runs results are contained in Appendix F. (continued)

Accuracy as used in this table reflects laboratory recovery and does not reflect the accuracy of the sampling procedure. Acceptable laboratory recoveries are typically reported as a range and can be used to represent the difference from the true value.

Accuracy for metals was assessed by post-digestion and pre-digestion laboratory spikes. This table is based on post-digestion laboratory spikes. Additional information is contained in Appendix H.

Precision for PAH analyses also determined by replicate runs (Appendix F).

Accuracy for PAH analyses also determined by pre-sampling surrogate spikes (field spikes) and blank matrix spikes.

RPD = Relative Percent Difference.
NA = Not available.
NC = Not calculated; analyte reported as not detected in two or more runs.
MSA = Sample analysis performed by method of standard additions.
NP = Not performed.

TABLE 5-4
SUMMARY OF PRECISION AND ACCURACY ESTIMATES
SITE 121

Measured Parameter	How Measured	Objectives		Measured	
		Precision	Accuracy	Precision	Accuracy
PCB in Exhaust Gas	Precision-Matrix Spike Duplicate Accuracy-Pre-Extraction Surrogate Spikes	50% RPD	50-150%	13% RPD	55%
Formaldehyde in Exhaust Gas	Precision - Replicate Runs Accuracy - Spiked Samples	10% RPD	60-140%	38% RPD	97%
Benzene and Toluene in Exhaust Gas	Precision - Replicate Runs Accuracy - Spiked Samples				
Benzene		20% RPD	70-130%	17% RPD	NP
Toluene		20% RPD	70-130%	16% RPD	NP
Major and Minor Components in Natural Gas	Precision-Replicate Runs Accuracy-Standard Reference Material	10% RPD	80-120%	0.8% RPD	100%

Precision for Formaldehyde also assessed by replicate runs and multiple pre- and post- test reagent blanks (Appendices E and F).
Accuracy as used in this table reflects laboratory recovery and does not reflect the accuracy of the sampling procedure. Acceptable laboratory recoveries are typically reported as a range and can be used to represent the difference from the true value.
Accuracy for Formaldehyde determined from laboratory matrix spikes. A trip spike indicated 131% recovery.
Precision for Benzene and Toluene also determined by replicate runs (Appendix F).
RPD = Relative Percent Difference.
NP = Not Performed.

5.4.1 Metals

Precision

The precision of metals analyses of flue gas samples can be estimated by the results of duplicate laboratory analyses. The precision data on duplicate analyses were compared to the precision objective of 10% RPD.

All metals met this criteria with the exception of arsenic (61%) and nickel (26%). Duplicate analysis was not performed for lead, as it was analyzed by the method of standard additions (MSA). Beryllium, cadmium, cobalt, mercury (in the HNO_3 fraction), and selenium were not detected and thus precision could not be calculated.

Analysis results for metals sample run 2 indicated sample contamination because of high chromium, copper and nickel concentrations; therefore, the results for the sample were not used to calculate average concentrations.

Precision for total metals was also calculated based on replicate runs. This type of precision estimate should be more variable than that obtained from duplicate analyses due to variability in the process and sampling. Since only two of the three metals runs were used for calculations, the total precision is calculated as an RPD -- not a CV. The total precision data on replicate runs were compared to an RPD objective of $<20\%$. Of all the detected elements, only lead (3%) and molybdenum (9%) met this objective.

Accuracy

The accuracy of metals analyses was determined from spiked samples. A spike recovery objective of 75-125% is specified by the multi-metals analysis. Typically if the recovery is not within $\pm 25\%$ of nominal, the laboratory attempts to analyze the sample using either an alternate instrumental technique or by the method of standard additions (MSA). In these samples, lead recovery was poor and graphite furnace analysis using the method of standard additions was performed.

Spike recoveries for all metals except nickel (70%) met the objective.

Blank Effects

Low levels of five metals (arsenic, barium, chromium, copper, and lead) were found in the reagent blank. Low levels of nine metals (arsenic, barium, chromium, copper, lead, manganese, molybdenum, nickel, and phosphorus) were found in the laboratory method blank. Laboratory and reagent blank levels are presented in Table H-1. The reagent blank was subtracted from the sample results to obtain the final results for five metals. The metals results affected and the blank correction contributions were: arsenic (22%), barium (11%), chromium (10%), copper (29%), and lead (10%). The laboratory method blank was subtracted from the

sample results to obtain the final results for phosphorus. The blank correction contribution for phosphorus was 52%. Uncorrected field blank levels were higher than 50% of the uncorrected measurements for the following detected metals: arsenic (73%), lead (100%), manganese (96%), molybdenum (97%), and phosphorus (102%). Laboratory blank levels at 56% of the uncorrected sample value for arsenic, 50% for manganese and 52% for phosphorus indicate a possibility of laboratory contamination.

Conclusions

Analysis for nickel had spike recoveries lower than the objective. Duplicate analysis for arsenic had an RPD of 61%. One of the three metals runs showed contamination and was not used to calculate average concentrations. Field blank levels were higher than 50% of the exhaust gas values for arsenic, lead, manganese, molybdenum, and phosphorus.

5.4.2 Polycyclic Aromatic Hydrocarbons

Precision

Only three PAH species were detected: naphthalene, phenanthrene, and 3-methylnaphthalene. Precision was determined by duplicate blank matrix spikes. A data quality objective of <50% RPD was set for PAH samples. Phenanthrene met this objective, while naphthalene (77%) did not. Duplicate matrix spikes were not performed for 3-methylnaphthalene.

Accuracy

The accuracy of the PAH analyses was assessed by the internal recovery of deuterated standards added to each sample before extraction. Acceptable recovery is 50-150%. The recoveries of all detected PAH species were acceptable, ranging from 59-96%. Other species not detected in the exhaust gas were also within the objective accuracy range, with the exception of one benzo(a)pyrene sample which had a recovery of 42%.

Blank Effects

All PAH species, except for naphthalene, were not detected in the laboratory method blank at 0.008-0.13 ug per sample. Naphthalene was detected in the method blank at 2.9 ug per sample, which was 33% of the average sample value. Of the detected PAH species, only naphthalene had a field blank level which was higher than 50% of the average uncorrected sample measurements with a value of 143%. Naphthalene is a suspected degradation product of a common contaminant to the XAD-2 resin used in the sampling train. Typically, all samples using this resin are biased high for naphthalene, though it is difficult to evaluate the extent of the high bias.

Conclusion

PAH results are acceptable; however, naphthalene field blank levels are greater than 50% of the sample levels which may indicate a high bias in sample results.

5.4.3 PCB

Precision

Precision for exhaust gas PCB samples was determined by duplicate blank matrix spike results. Precision for all PCB species met the objective of <50% RPD, ranging from 5-31%.

Accuracy

Blank matrix spike recoveries for all PCB species ranged from 55-118%, meeting the recovery objective of 50-150%. All internal recoveries, with the exception of one monochlorobiphenyl spike (46%), met the recovery objective of 50-150%.

Blank Effects

No PCB species were detected in the method blank, field blank, or exhaust gas samples.

Conclusion

PCB analytical quality assurance results for exhaust gas samples are considered acceptable.

5.4.4 Volatile Organic Compounds

Precision

Precision for VOC compounds was calculated based on duplicate analyses of exhaust gas samples. One benzene duplicate (30%) and one toluene duplicate (21%) analysis exceeded the DQO of <20% RPD. High RPDs are typical when analyzing concentration levels at or near the reporting limit. One toluene sample analysis indicated contamination because it was 14 times higher than the other two runs performed within the same source, and the result was not used. One Tedlar bag sample leaked during transport and was not analyzed.

Accuracy

Matrix spikes were not performed.

Blank Effects

Benzene was not detected in the Tedlar bag blank, while toluene was detected at a concentration of 4.4 $\mu g/Nm^3$. Blank levels were not subtracted to obtain final sample results.

Conclusion

Precision for VOC analysis was good with two exceptions. The accuracy of the analysis could not be assessed for this test series because of a lack of sample spikes. Blanks levels were acceptable. One sample indicated contamination, and another leaked during transport.

5.4.5 Formaldehyde

Precision

Precision was determined by duplicate analysis of formaldehyde samples. Two of the four duplicate analysis exceeded the DQO of $<10\%$ RPD with values of 70% and 75%.

Accuracy

The accuracy of the analysis was estimated from matrix spike recoveries. Matrix spike recoveries averaged 97%. Field and trip spikes were also collected. A field spike is a vial of DNPH solution spiked with formaldehyde that is connected to the sampling equipment, leak checked, and recovered. Field spike recovery was 140%. A trip spike is a spiked vial of DNPH solution that is never opened. Trip spike recovery was 131%. All spike recoveries met the DQO of 60-140%.

Blank Effects

Sample values were not corrected for blank values of DNPH or for field blank levels. Field blank levels were below sample levels with the exception of three field blank vials, which contained twice the level of formaldehyde as the samples. The remaining three field blank results were not higher than half the sample result values. Field blank results indicate that there is a possible positive bias to the sample results.

Conclusion

Sample precision does not meet the data objective. Accuracy as measured by samples, field spike and trip spike analysis is acceptable. Field blank levels indicate the possibility of a positive bias in the results.

5.4.6 Fuel Analysis

Precision

Precision was determined by duplicate analysis of the natural gas fuel samples. The data quality objective for this analysis was 10% RPD. The average RPD for detected major and minor components was 0.82%. Sample precision is determined by replicate sample analysis, with a DQO of 20% CV. The average CV for the on-site analysis of the three fuel replicates was 3.9%. All species met the objective with the exception of hydrogen (25%).

Accuracy

Accuracy is estimated by analysis of a laboratory check standard. The average recovery of this standard was 100%, and all species met the data quality objective of 90-100% recovery. No matrix spikes were performed.

Blank Effects

No blank analysis was performed.

Conclusion

Precision for fuel analysis based on duplicate analysis was acceptable. Sample precision based on replicate runs was also acceptable, with the exception of hydrogen. A laboratory check standard met the recovery objective. No blank analysis was performed.

5.5 STACK SAMPLING QUALITY CONTROL RESULTS

Sampling quality control was well documented in this program. It included calibration sheets for most of the equipment used, including the gas meters, portable O_2 meters, and CEM calibration. Also on file are calibrations for temperature indicators and pitot assemblies. Gas meters are calibrated before and after sampling and can differ no more than 3% from the original meter calibration. The sampling data were evaluated and comments were made on the sampling data sheets about the sampling locations, techniques used, and specific tests comments. In general, a methodical and conservative approach was employed to collect the samples according to the specifications.

The precision of the sampling can be estimated by comparing results for various parameters of the replicate samples, notably velocity, moisture content, and gas composition. A comparison of the measured flow rate to calculated flow rates from F-factor determination was made.

The accuracy of the sampling is usually assumed from the calibration and proper operation of the equipment and from historical validation of the methods. Field blanks were

used to assess any biases that may be caused by contamination of the equipment, location, or operator errors. Field blank values were not subtracted from tests results. Field blanks were performed for all tests except the VOC trains. Reagent blanks were collected for all tests except the PAH/PCB tests, where laboratory reagent blanks were used.

5.6 MATERIAL BALANCE RESULTS

At Site 121, only two streams were used to define the material balance: natural gas fuel and exhaust gas stack samples. Stream flow rates and concentrations, and the bias and precision errors associated with those measurements, were entered into a statistical error propagation model to estimate the overall material balance closure. A detailed discussion of this statistical error propagation analysis is presented in Section 5.0.

Closure is defined as the ratio of output to input mass. A 100% closure indicates perfect agreement of the measured input and output mass flow rates. Closures of 70-130 % have been set as a goal for this project. This range reflects the typical level of analytical uncertainty. Closures outside this range may indicate measurement problems in one or more of the sample matrices or a systematic bias imposed by the experimental design.

Of all the metals, only arsenic was detected in both the natural gas fuel and the exhaust gas. Therefore a mass balance can only be computed for this species. The arsenic emission factor in the natural gas fuel was 0.25 lb/10^{12} Btu, and the emission factor was 0.19 lb/10^{12} Btu in the exhaust gas, resulting in a closure of 78%. The arsenic mass balance was calculated from one fuel sample and two exhaust gas samples, so their value is not known with a high degree of certainty. Because of the low levels of arsenic in the fuel and exhaust gas, analytical factors such as blank levels impact the mass balance results significantly. Mercury was detected at 0.0013 lb/10^{12} Btu in the natural gas sample, but the multimetal train analysis was not sensitive enough to detect mercury in the exhaust gas.

SECTION 6.0

EXAMPLE CALCULATIONS

This section presents the methodology and sample calculations used to develop the results presented in Sections 3.0 and 4.0. Specifically, the calculation of stream flow rates, confidence intervals and unit-energy-based results are discussed.

6.1 STREAM FLOW RATES

Appendix D presents information about the stream flow rates measured or calculated at Site 121 during the sampling period.

Stack gas flow rates were calculated from natural gas flow, higher heating value and fuel F-factor, as described in Section 5.2. Although flue gas flow rates were measured directly during isokinetic sampling, the calculated flow rate is considered to be more accurate for this location.

Natural gas flow rates were determined using control room instrumentation.

6.2 MEANS AND CONFIDENCE INTERVALS FOR STREAM CONCENTRATIONS

The mean concentrations and 95% confidence intervals (CIs) about the mean were calculated for each target substance in the streams sampled. The means were calculated according to the conventions listed in Section 3.0. The equations used to calculate the 95% confidence intervals are presented in Appendix F.

Example calculations for naphthalene in the flue gas follow here; these results were shown in Table 3-3.

The concentration data (in $\mu g/Nm^3$) given for naphthalene in Table 3-3 are:

Run 1	Run 2	Run 3
1.00	2.22	1.36

The mean is calculated from the individual run totals:

Mean = (1.20 + 2.22 + 1.36)/3 = 1.59

The sample standard deviation of the individual run totals is calculated:

$$S_p = \sqrt{[(1.20-1.59)^2 + (2.22-1.59)^2 + (1.36-1.59)^2]\ /2} = 0.549$$

The standard deviation of the average is calculated according to the equation in Appendix F for N = 3:

$$S_{\overline{pi}} = 0.549/\sqrt{3}$$

$$= 0.317$$

The bias error is found by root-sum-squaring the product of the bias error and the sensitivity from each run (see Appendix F). According to the conventions listed in Section 3.0, no bias error is assigned to values above reporting limits, whereas a bias error of one-half the reporting limit is assigned to values below reporting limits. Since all values are above the detection limit, no bias errors are assigned to each of the three values. The sensitivity of the mean to each run in this case is 1/3. An additional bias of 10% of the average sample value or 0.159 is introduced because of the difference in particle collection from ideal conditions during isokinetic tests.

$$\beta_r = \sqrt{((1/3 \times 0)^2 + (1/3 \times 0)^2 + (1/3 \times 0)^2)^2 + (0.159)^2}$$

$$= \sqrt{(0)^2 + (0.159)^2}$$

$$= 0.159$$

The total uncertainty in the result is found from:

$$U_r = \sqrt{\beta_r^2 + (t \times S_p)^2}$$

$$= \sqrt{(0.159)^2 + (4.3 \times 0.317)^2}$$

$$= 1.38$$

Thus, the naphthalene result is reported as 1.59 $\pm$ 1.38 $\mu g/Nm^3$.

6.3 UNIT ENERGY EMISSION FACTORS

In addition to the gas-phase concentrations, unit-energy-based emission factors expressed as lb/10^{12} Btu have been developed for each target substance. These values were determined by calculating the concentration of a substance in the flue gas (lb/ft^3) and multiplying by the fuel F-factor and O_2 correction, according to EPA Method 19.

The equation used for trace species emissions is:

$$lb/10^{12}\ Btu = \mu g/m^3 \times m^3/35.31\ ft^3 \times 10^6 \mu g/g \times lb/454g$$

$$\times\ F\text{-}factor\ @\ 0\%\ O_2 \times 10^{-6} \times 20.9/(20.9 - \%\ O_2)$$

The 95% confidence intervals for emission factors were calculated according to the equations presented in Appendix F. For each parameter (concentration, unit heat rate, and unit load) the mean, standard deviation, number of points, and bias estimates were used to calculate the combined uncertainty in the mean emission factors.

SECTION 7.0

GLOSSARY

ASTM	American Society for Testing and Materials
BOOS	Burners-Out-of-Service
Btu	British Thermal Unit
CAAA	Clean Air Act Amendments of 1990
CARB	California Air Resources Board
CEMS	Continuous Emissions Monitoring System
CI	Confidence Interval
CV	Coefficient of Variation
CVAAS	Cold Vapor Atomic Absorption Spectrophotometry
DL	Detection Limit
DQO	Data Quality Objective
dscfm	Dry Standard Cubic Feet per Minute (1atm, 68°F)
EPA	U.S. Environmental Protection Agency
FCEM	Field Chemical Emissions Monitoring
FGR	Flue Gas Recirculation
GC/AED	Gas Chromatography with Atomic Emission Detection
GC/ELCD	Gas Chromatography with Electroconductivity Detection
GC/FID	Gas Chromatography with Flame Ionization Detection
GC/FPD	Gas Chromatography with Flame Photometric Detection
GC/MS	Gas Chromatography with Mass Spectrometer
GC/SCD	Gas Chromatography with Sulfur Chemiluminescence Detection
GC/TCD	Gas Chromatography with Thermal Conductivity Detection
GFAAS	Graphite Furnace Atomic Absorption Spectrophotometry
HHV	Higher Heating Value
HPLC	High Pressure Liquid Chromatography
HRGC/FID	High Resolution Gas Chromatography with Flame Ionization Detection
HRGC/LRMS-SIM	High Resolution Gas Chromatography/Low Resolution Mass Spectrometry with Selected Ion Monitoring
IC	Ion Chromatography
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectroscopy
ICP-Hydride	Inductively Coupled Plasma with Hydride Generation
ID	Induced Draft
LCS	Laboratory Check Standards
MMBtu	Million British Thermal Units
MW	Megawatt
NC	Not Calculated

ND	Not Detected
NIST	National Institute of Standards and Technology
Nm^3	Dry Normal Cubic Meter (0°C, 1atm)
NM	Not Measurable
NP	Not Performed
NR	Not Reported
PAH	Polycyclic Aromatic Hydrocarbons
PISCES	Power Plant Integrated Systems Chemical Emission Study
ppmc	Parts Per Million Corrected to 3% O_2
QA/QC	Quality Assurance/Quality Control
RPD	Relative Percent Difference
RPDM	Relative Percent Difference from the Mean
UOM	Unit of Measure

APPENDIX A
SAMPLING AND ANALYTICAL SUMMARY

This appendix presents the methods used to collect, preserve and analyze each type of sample collected at Site 121. Summary tables presented include the following:

A-1	Reference Table for Sampling Methods
A-2	Stack Test Schedule
A-3	Sampling Train Configurations for Stack Samples
A-4	Sampling and Analytical Methods for Stack Samples
A-5	Sampling Schedule for Natural Gas Samples
A-6	Analytical Methods for Natural Gas Samples
A-7	Sample Handling and Preparation Procedures

Descriptions of the flue gas sampling trains and fuel sample collection methods follow the summary tables.

TABLE A-1
REFERENCE TABLE FOR SAMPLING METHODS
SITE 121

Stream	Target Substances	Collection Method
Stack	Metals: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Mn, Hg, Mo, Ni, P, Se, V	EPA Multi-Metals
	Polycyclic Aromatic Hydrocarbons/ Polychlorinated Biphenyls	CARB 429, 428
	Benzene, Toluene	CARB 410A (bags)
	Formaldehyde	CARB 430
Air Preheater Inlet	NO_x, CO, O_2, CO_2	EPA 7E, 10, 3A
	Total Hydrocarbons	EPA 25A
Natural Gas	Metals, heating value, hydrocarbons, non-hydrocarbons, sulfur compounds, oxygenated compounds, nitrogen compounds, halocarbons, radon	Grab samples

TABLE A-2
STACK TEST SCHEDULE
SITE 121

Test No.	Date	Time	Description
1-PAH	4/12/93	1350/2030	Polyaromatic Hydrocarbons/Polychlorinated Biphenyls
1-MTLS	4/12/93	1345/2030	Metals (As, Ba, Be, Cd, Cr, Co, Cu, Pb, Mn, Hg, Mo, Ni, Se, P, V)
2-PAH	4/13/93	0905/1525	Polyaromatic Hydrocarbons/Polychlorinated Biphenyls
2-MTLS	4/13/93	0905/1530	Metals (As, Ba, Be, Cd, Cr, Co, Cu, Pb, Mn, Hg, Mo, Ni, Se, P, V)
3-PAH	4/14/93	0845/1500	Polyaromatic Hydrocarbons/Polychlorinated Biphenyls
3-MTLS	4/14/93	0845/1505	Metals (As, Ba, Be, Cd, Cr, Co, Cu, Pb, Mn, Hg, Mo, Ni, Se, P, V)
3A-FORM	4/14/93	0945/1045	Formaldehyde
3B-FORM	4/14/93	1125/1225	Formaldehyde
3C-FORM	4/14/93	1245/1345	Formaldehyde
3A-VOC	4/14/93	1000/1030	Benzene and Toluene
3B-VOC	4/14/93	1145/1215	Benzene and Toluene
3C-VOC	4/14/93	1245/1315	Benzene and Toluene
4A-FORM	4/15/93	2335/0035	Formaldehyde
4B-FORM	4/15/93	2335/0035	Formaldehyde
4A-VOC	4/15/93	2335/2355	Benzene and Toluene
4B-VOC	4/15/93	0005/0035	Benzene and Toluene
5A-FORM	4/15/93	0140/0240	Formaldehyde
5B-FORM	4/15/93	0140/0240	Formaldehyde
5A-VOC	4/15/93	0145/0205	Benzene and Toluene
5B-VOC	4/15/93	0215/0235	Benzene and Toluene
6A-FORM	4/15/93	0345/0445	Formaldehyde
6B-FORM	4/15/93	0345/0445	Formaldehyde
6A-VOC	4/15/93	0345/0405	Benzene and Toluene
6B-VOC	4/15/93	0415/0435	Benzene and Toluene

TABLE A-3
SAMPLE TRAIN CONFIGURATIONS
FOR STACK SAMPLES
SITE 121

Sample Train	Nozzle	Filter	Filter Holder	Probe	Sample Line	Impinger Contents #1	#2	#3	#4	#5
EPA Multi-Metals Draft Method 29	Glass	Method 5 ultrapure 110 mm filter	Method 5 glass	Glass	Teflon	100 ml 5% HNO_3/ 10% H_2O_2	100 ml 5% HNO_3/ 10% H_2O_2	Empty	100 ml 4% $KMnO_4$/ 10% H_2SO_4	300-400 g silica gel
Semi-VOST CARB 429 CARB 428	Glass	Method 5 toluene-rinsed 110 mm filter	Method 5 glass	Glass	Teflon to XAD-2 resin column	Empty stub-stem	100 ml organic-free D.I. H_2O	Empty	300-400 g silica gel	N/A
Benzene/Toluene CARB 410A	N/A	N/A	N/A	Glass	Teflon, 1/4"	Sample collected over 30 minutes in Tedlar bag				
						Midget Impingers				
Formaldehyde CARB 430	N/A	47 mm in-stack fiberglass filter to prevent particulate interference	Method 5 Teflon-coated stainless steel	Glass	Teflon, 1/8"	10 ml DNPH	10 ml DNPH	Empty	10-20 ml silica gel	N/A

N/A = Not Applicable

TABLE A-4
SAMPLING AND ANALYTICAL METHODS FOR STACK SAMPLES SITE 121

Parameter	No. of Replicates	Duration of Test (Minutes)	Sample Rate	Collection and Preparation Reference Method	Measurement Principle	Analytical Reference Method	Method Detection Limit	Comments
Metals:	3	360	1 m^3/hour	EPA Multi-Metals				
Arsenic					ICP-Hydride	EPA SW486 7061	0.05 $\mu g/m^3$	
Barium					ICP-AES	EPA SW846 6010	0.08 $\mu g/m^3$	
Beryllium					ICP-AES	EPA SW846 6010	0.02 $\mu g/m^3$	
Cadmium					ICP-AES	EPA SW846 6010	0.05 $\mu g/m^3$	
Chromium					ICP-AES	EPA SW846 6010	0.08 $\mu g/m^3$	
Cobalt					ICP-AES	EPA SW846 6010	0.14 $\mu g/m^3$	
Copper					ICP-AES	EPA SW846 6010	0.08 $\mu g/m^3$	
Lead					GFAAS	EPA SW846 7421	0.28 $\mu g/m^3$	Method of Standard Additions
Manganese					ICP-AES	EPA SW846 6010	0.11 $\mu g/m^3$	
Mercury					CVAAS	EPA SW846 7470	0.46 $\mu g/m^3$	
Molybdenum					ICP-AES	EPA SW846 6010	0.11 $\mu g/m^3$	
Nickel					ICP-AES	EPA SW846 6010	0.28 $\mu g/m^3$	
Phosphorus					ICP-AES	EPA SW846 6010	0.04 $\mu g/m^3$	
Selenium					ICP-Hydride	EPA SW486 7741	0.85 $\mu g/m^3$	
Vanadium					ICP-AES	EPA SW846 6010	0.08 $\mu g/m^3$	
Volatile Organic Compounds:	3	30	0.2 ℓ/min	CARB 410A	GC/MS	CARB 410A, EPA TO-14		Collected in Tedlar bags.
Benzene							0.33 $\mu g/m^3$	
Toluene							0.38 $\mu g/m^3$	
Formaldehyde:	3	60	0.07 ft^3/min	CARB 430	HPLC	CARB 430	0.8 $\mu g/m^3$	Collected in midget impingers.

(continued)

TABLE A-4 (continued)
SAMPLING AND ANALYTICAL METHODS
FOR STACK SAMPLES
SITE 121

Parameter	No. of Replicates	Duration of Test (Minutes)	Sample Rate	Collection and Preparation Reference Method	Measurement Principle	Analytical Reference Method	Method Detection Limit	Comments
Polycyclic Aromatic Hydrocarbons:	3	360	1 m^3/hour	CARB 429	HRGC/LRMS-SIM	CARB 429		
Naphthalene							0.019 $\mu g/m^3$	CARB 429 with isotope dilution used where isotopically labeled standards were available.
Acenaphthylene							0.002 $\mu g/m^3$	
Acenaphthene							0.005 $\mu g/m^3$	
Fluorene							0.006 $\mu g/m^3$	
Phenanthrene							0.004 $\mu g/m^3$	
Anthracene							0.004 $\mu g/m^3$	
Fluoranthene							0.003 $\mu g/m^3$	
Pyrene							0.003 $\mu g/m^3$	
Benzo(a)anthracene							0.005 $\mu g/m^3$	
Chrysene							0.004 $\mu g/m^3$	
Benzo(b)fluoranthene							0.003 $\mu g/m^3$	
Benzo(k)fluoranthene							0.004 $\mu g/m^3$	
Benzo(a)pyrene							0.006 $\mu g/m^3$	
Indeno(1,2,3-cd)pyrene							0.010 $\mu g/m^3$	
Dibenzo(a,h)anthracene							0.005 $\mu g/m^3$	
Benzo(g,h,i)perylene							0.006 $\mu g/m^3$	
2-Methylnaphthalene							0.004 $\mu g/m^3$	Method of internal standardization used for 2-methylnaphthalene, 3-methylcholanthrene and 7,12 dimethylbenzo(a)anthracene
7,12-Dimethylbenz(a)anthracene							0.005 $\mu g/m^3$	
3-Methylcholanthrene							0.025 $\mu g/m^3$	
PCB:	3	360	1 m^3/hr	CARB 428	HRGC/LRMS-SIM	CARB 428	0.001-0.004 $\mu g/m^3$	Analysis from PAH train.
PCB isomer groups by level of chlorination. Total mono- through decachlorobiphenyls								

NOTES: The metals detection limits are calculated using an average sample volume of 6.15 m^3.
The PAH detection limits are calculated using an average sample volume of 5.22 m^3.
The formaldehyde detection limit is calculated using an average sample volume of 7.99 m^3.
NO_x, CO, O_2 and CO_2 determined in conjunction will all tests by EPA Methods 7E and 3A.
Total hydrocarbons determined in conjunction with tests 3-6 by EPA Method 25A.
Velocity and moisture measured in conjunction with all isokinetic tests by EPA Methods 2 and 4.

TABLE A-5
SAMPLING SCHEDULE FOR NATURAL GAS SAMPLES
SITE 121

Date	Sample Name	Number of Samples	Time
4/13/93	IGAS 0913	1	0931
4/13/93	IGAS 0914	1	1115
4/13/93	IGAS 0915	1	1427

Note: Samples listed were collected for on-line composition and heating value analysis. Additional sample types were collected for trace species analysis; however, collection times were not provided by IGT.

TABLE A-6
ANALYTICAL METHODS FOR NATURAL GAS SAMPLES
SITE 121

Parameter	Measurement Principle	Reference Method	Method Detection Limit	Comments
Major hydrocarbons	GC/FID, GC/TCD	ASTM D-1945, D-1946	0.001-0.03 mole%	
Non-hydrocarbons (O_2, H_2O, He, H_2, N_2, CO_2 CO)	GC/FID, GC/TCD	ASTM D-1945, D-1946	0.002-0.03 mole% 10 ppm (H_2O)	
C5 + hydrocarbons	HRGC/FID	Modified GPA	0.02-1 ppm	
Sulfur compounds	GC/FPD, GC/SCD		0.02-1 ppm	
Oxygenated compounds	GC/AED, HPLC		0.01-1 ppm	
Nitrogen compounds	GC/AED		0.5-4 ppm	
Halocarbons	GC/ELCD		0.01-1 ppm	
Trace elements	GC/AED		0.002-1 ppm	
NO	Chemiluminescence		0.1 ppm	
NO_x	IC		0.3 ppm	
Radon	Gamma spectroscopy		1 pCi//	

TABLE A-7
SAMPLING HANDLING AND PREPARATION PROCEDURES
SITE 121

Sample Type	Parameter	Sample Fraction Description	Sample Containers	Sample Handling and Preservation	Laboratory Preparation Procedure
Flue Gas Samples	Metals	Filter	Petri dish	Seal	Parr Bomb HF/HNO_3 digestion
		Front-half nitric peroxide rinse	500 ml acid-washed amber HDPE Nalgene	Seal and mark liquid level	Combine with filter, Parr Bomb digestion
		5% HNO_3/ 10% H_2O_2 impinger rinse	1000 ml acid-washed amber HDPE Nalgene	Seal and mark liquid level	Remove Hg fraction, evaporate remainder at 70°C with excess HNO_3 (pH 1)
		4% $KMnO_4$/10% H_2SO_4 impinger rinse	500 ml acid-washed amber HDPE Nalgene	Seal and mark liquid level	Digest with H_2SO_4
				All fractions: ship at conclusion of metals tests	

(continued)

TABLE A-7 (continued)
SAMPLING HANDLING AND PREPARATION PROCEDURES
SITE 121

Sample Type	Parameter	Sample Fraction Description	Sample Containers	Sample Handling and Preservation	Laboratory Preparation Procedure
Flue Gas Samples	PAH/PCB	Filter	Hexane-rinse, foil-lined petri dish	Seal, store at ≤ 4°C	Soxhlett extraction
		XAD-2 column	Not applicable	Wrap with foil to keep XAD-2 from exposure to light. Store at ≤ 4°C	Soxhlett extraction
		Front-half organic rinse	500 ml organic-free amber glass bottle with Teflon-lined lid	Seal and mark liquid level Store at ≤ 4°C	Soxhlett extraction
		Back-half organic rinse	500 ml organic-free amber glass bottle with Teflon-lined lid	Seal and mark liquid level Store at ≤ 4°C	Soxhlett extraction
		Back-half water impinger rinse	500 ml organic-free amber glass bottle with Teflon-lined lid	Seal and mark liquid level Store at ≤ 4°C	Soxhlett extraction
				All fractions: Sample to be extracted within 7 days of sampling; analysis to be performed within 40 days. Ship at conclusion of PAH tests.	
	Benzene, Toluene	Tedlar bag	Not applicable	Seal valve with tape to prevent accidental release of sample. Store bag in light-free container.	Cryogenic pre-concentration
	Formaldehyde	DNPH filtration and line rinse	Organic free DI H_2O washed 40 ml glass sample vials with teflon lined lid	Seal and mark liquid level. Store at ≤ 4°C. Analyze within 7 days. Ship at conclusion of formaldehyde tests.	Extraction

Natural Gas Collection Procedures

Natural Gas

Natural gas sampling and analysis was performed by IGT Analytical. IGT conducted triplicate on-line measurements of natural gas composition (major and minor components) and heating value for EPA Method 19 F-factor calculations. Additional samples were collected and analyzed for the target compounds listed below:

- Non-hydrocarbons: He, H_2, O_2, CO, CO_2, H_2O, As, Hg
- Hydrocarbons: C_1-C_{14} paraffins, C_2-C_3 olefins, BTEX, PAH
- Oxygenated compounds: Acetone, methanol, glycols, aldehydes, phenols, cresols
- Nitrogen compounds: NH_3, NO/NO_x, amines, N-heterocycles
- Halocarbons: Freons and landfill gas components (C_1-C_3, cyclic, aromatic), PCBs
- Sulfur compounds: H_2S, SO_2, COS, CS_2, sulfur odorants and derivatives
- Metals: Volatile compounds of As, Co, Cu, Fe, Ge, Hg, Ni, P, Pb, Sb, Se, Si, Sn
- Others: NORM (naturally occurring radioactive materials including radon)

The characterization and quantification of trace species was not limited to these components. An initial screening of the natural gas determined which components were present and any component found in the initial screening was quantified.

An MCM hygrometer from Stephens Analytical was used for moisture determination in a range of 10 to 6000 ppmv. An on-line Delta F trace oxygen analyzer with an Ascarite scrubber to remove CO_2 was used to measure oxygen in a range of 1 to 1000 ppmv. A Scintrex Model OVD-229 sulfur analyzer was used to monitor odorants and H_2S in natural gas at a concentration level of 0.1 to 10 ppmv.

Samples collected by IGT for laboratory analysis include the following:

- Whole gas samples
- Liquefied fractions (cryogenic sampling train at -70°C)
- Lean gas (after the cryogenic sampler)
- Particulate samples (collected upstream of sampler)
- Pipeline condensate
- Pipeline deposits (from brush-piggings, if available)

Samples were collected on-site using different sampling techniques to preserve and/or preconcentrate the compounds of interest for later analysis in IGT's Chicago laboratory. A 3/8" automatic insertion probe with a 3/4" pipe thread connector from Welker Engineering was used to place the tip of the probe at the center third of the pipeline to assure representative sampling. A proportional sampler from Welker Engineering was also used to sample pipeline gas with a sampling rate of 3 ml/min.

over a long span of time to collect a representative whole gas sample. Gas cylinders internally coated with phenolic resin were used to collect gas samples.

For trace organic constituents a cryogenic system (Figure 2-3), which operates at -70°C (-94°F) and at line pressures up to 12.4 x 10^6 Pa (1800 psig) was employed. The system is designed to condense, preconcentrate and recover hydrocarbons heavier than butanes for later analysis of hydrocarbons up to C_{14}. This cryogenic sampler uses a heat exchange coil made of approximately 10 feet of 1/4 inch O.D. 316 S.S. tubing wound in a helical form, which is attached to a single ended 150-ml 316 S.S. sample cylinder through a Tee connector. The gas flows downward through the coil and cylinder and exists through a straight S.S. tubing. Two valves are installed on the other end of each tubing above the level of chilling fluid.

An immersion cooler (FTS Model FC-100) is used for constant temperature control of the cryogenic bath containing one part of methanol and 3 parts of isopropanol. Dry ice is used to accelerate the cooling rate to bring the initial temperature quickly down to -70°C.

Natural gas samples for inorganic trace element analysis were collected on a variety of solid sorbent tubes. Mercury was collected at a flow rate of 1 L/min using two 6 mm ID sorbent tubes packed with 1% gilded silica beads. Arsenic was collected at a rate of 1 L/min with a 6 mm tube packed with 25% $FeCl_3$. Radon was collected at a rate of 1.2 L/min with two 2 x 3" carbon cartridges.

Stack Sample Collection and Analysis Procedures

Multi-Metals Train

Stack samples were withdrawn isokinetically with particulate emissions collected on a heated filter and gaseous emissions collected in a series of iced impingers. The first two impingers contained 5% HNO_3/10% H_2O_2, the fourth impinger contained 4% $KMNO_4$/10% H_2SO_4 and the fifth impinger contained silica gel. The third impinger was empty to prevent the permanganate solution in the fourth impinger from contaminating the first two impingers.

Decomposition of each sample fraction was per the EPA method. Whenever possible, decomposed sample portions were concentrated and combined with regard to preventing loss of volatile metals, to achieve the lowest detection limits possible for these samples. Materials collected in the sampling train were digested with acid solutions to solubilize inorganic target species and to remove organic constituents that may create analytical interferences. Acid digestion of the front-half and filter was performed using conventional Parr Bomb digestion techniques.

Reagent and filter blanks were analyzed for all trace metals. A spiked reagent blank for Hg and spiked reagent blank for all metals was analyzed to assess analytical recovery methods and to ensure that the decomposition procedure was accurate. Following the analysis of the samples and field blanks, a mandatory check for matrix effects and interferences was performed for each metal by spiking one outlet and one inlet sample. The inlet sample spikes were considered representative of the analytical technique because they were spiked at a level comparable to the sample concentrations. If the recovery was less than $\pm 25\%$ of nominal, the sample was run using the method of standard additions or an alternate technique if possible. One duplicate analysis was performed for each metal. A field blank was collected and analyzed from the inlet and the outlet locations. Analyses for the trace metals was performed by ICP-AES, GFAAS, or CVAAS absorption, depending upon the metal of interest.

Semi-Volatile Species

Triplicate samples for PAH and PCB were collected according to CARB Method 429 -September 12, 1989 version. In this procedure, a sample was collected isokinetically and passed through a heated filter followed by an XAD-2 sorbent module in a water-cooled condenser. The sorbent module was followed by an impinger train to collect moisture and any species that might pass through the resin.

At each sample location a full field blank train was assembled, recovered and analyzed. During the recovery procedure all glassware was rinsed three times each with organic free methanol, toluene and methylene chloride. The solvent rinses were combined with the filter and sorbent module for extraction and final analysis for each train.

Prior to release to the field, each XAD-2 resin trap was spiked with deuterated standards to assess field losses or gains of PAH and PCB species. In addition, sixteen surrogate standards were added to each sample prior to the extraction step to provide recovery corrected results. Deuterated standards were not available for 2-Methylnapthalene, 3-Methylcholanthrene, or 7,12-Dimethylbenzo(a)anthracene; the method of internal standardization was used for these species. Following extraction and cleanup, a portion of the processed extract from each sample was analyzed for PAH and PCB by HRGC/LRMS-SIM.

Benzene and Toluene

Tedlar bag samples were drawn simultaneously at a single point in the stack. The samples were collected according to CARB 410A using GC/MS as the method of analysis. Duplicate analyses were performed on four samples. One sample was then spiked with benzene and toluene and reanalyzed to assess recovery.

Formaldehyde

Triplicate samples for formaldehyde were collected at a single point in the stack per CARB Method 430. The flue gas was drawn non-isokinetically through a heated filter and into acidic 2,4 dinitrophenylhydrazine (DNPH) solution contained in midget impingers. The analysis for formaldehyde was performed by reverse-phase HPLC with a UV Detector. The collection solution was analyzed before release to the field to verify that there was no significant level of detectable formaldehyde. All samples were kept cold and sealed. Three field blanks were taken and analyzed by attaching blank vials of DNPH to the sampling equipment and recovering it the same way as a sample. In this way, blank DNPH solution is exposed to the ambient air and the sampling equipment for the same period of time as the sample vials. A field spike that contained 5.0 μg of formaldehyde was prepared, exposed to sampling conditions using the same procedure as the field blanks and analyzed, along with a trip blank and a trip spike (neither of which were opened).

NO_x, CO, O_2 and CO_2

Gaseous species were measured continuously using a multiprobe array in the economizer outlet duct using a continuous emissions monitoring system. Additionally, portable O_2 meters were used with each sample train to provide sample-specific O_2 data.

Velocity and Moisture

Stack gas velocity and moisture content were measured by EPA Methods 2 and 4 in conjunction with every isokinetic test.

APPENDIX B

FCEM SITE 121 INDIVIDUAL STREAM CONCENTRATIONS

This appendix presents the Site 121 sampling results that were used to calculate the emissions and mass balances presented in this report. Results for the flue gas and for the natural gas are presented.

The following data flags are used in this table:

ND<	Not detected at less than the reporting limit
NA	Not analyzed
@	Concentration is less than five times the reporting limit
B	Blank correction exceeded 50% of uncorrected result
F	Field blank exceeded 50% of uncorrected result

APPENDIX B
SITE 121 DATA USED IN CALCULATIONS

Stream	Substance	Method	UOM	Run 1	Run 3	Average Used
Stack Gas, Metals	Arsenic	ICP-Hydride	ug/Nm3	0.24F	0.31F	0.27F
Stack Gas, Metals	Barium	ICP-AES	ug/Nm3	9.7	6.1	7.9
Stack Gas, Metals	Beryllium	ICP-AES	ug/Nm3	ND< 0.02	ND< 0.01	ND< 0.02
Stack Gas, Metals	Cadmium	ICP-AES	ug/Nm3	0.11@	ND< 0.04	0.06
Stack Gas, Metals	Chromium	ICP-AES	ug/Nm3	2.1	0.90	1.5
Stack Gas, Metals	Cobalt	ICP-AES	ug/Nm3	ND< 0.15	ND< 0.15	ND< 0.15
Stack Gas, Metals	Copper	ICP-AES	ug/Nm3	2.1	1.2	1.6
Stack Gas, Metals	Lead	GFAAS	ug/Nm3	0.81@F	0.79@F	0.80@F
Stack Gas, Metals	Manganese	ICP-AES	ug/Nm3	0.68F	0.54@F	0.61F
Stack Gas, Metals	Mercury	CVAAS	ug/Nm3	ND< 0.42	ND< 0.54	ND< 0.54
Stack Gas, Metals	Molybdenum	ICP-AES	ug/Nm3	2.7F	2.5F	2.6F
Stack Gas, Metals	Nickel	ICP-AES	ug/Nm3	2.1	1.2@	1.6
Stack Gas, Metals	Selenium	ICP-Hydride	ug/Nm3	ND< 0.04	ND< 0.04	ND< 0.04
Stack Gas, Metals	Phosphorus	ICP-AES	ug/Nm3	5.9F	6.8F	6.3F
Stack Gas, Metals	Vanadium	ICP-AES	ug/Nm3	0.71	0.57	0.64

Stream	Substance	Method	UOM	Run 1	Run 2	Run 3	Average Used
Stack Gas, PAH	Naphthalene	HRGC/LRMS-SIM	ug/Nm3	1.20F	2.22F	1.36F	1.59F
Stack Gas, PAH	Acenaphthylene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.014	ND< 0.004	ND< 0.006	ND< 0.014
Stack Gas, PAH	Acenaphthene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.011	ND< 0.006	ND< 0.003	ND< 0.011
Stack Gas, PAH	Fluorene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.026	ND< 0.013	ND< 0.010	ND< 0.026
Stack Gas, PAH	Phenanthrene	HRGC/LRMS-SIM	ug/Nm3	0.054	ND< 0.015	ND< 0.010	0.022
Stack Gas, PAH	Anthracene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.040	ND< 0.010	ND< 0.005	ND< 0.040
Stack Gas, PAH	Fluoranthene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.011	ND< 0.005	ND< 0.002	ND< 0.011
Stack Gas, PAH	Pyrene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.013	ND< 0.005	ND< 0.005	ND< 0.013
Stack Gas, PAH	Benz(a)anthracene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.007	ND< 0.004	ND< 0.005	ND< 0.007
Stack Gas, PAH	Chrysene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.009	ND< 0.006	ND< 0.006	ND< 0.009
Stack Gas, PAH	Benzo(b)fluoranthene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.005	ND< 0.004	ND< 0.003	ND< 0.005
Stack Gas, PAH	Benzo(k)fluoranthene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.012	ND< 0.004	ND< 0.003	ND< 0.012
Stack Gas, PAH	Benzo(a)pyrene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.011	ND< 0.003	ND< 0.005	ND< 0.011
Stack Gas, PAH	Indeno(1,2,3-cd)pyrene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.007	ND< 0.004	ND< 0.004	ND< 0.007
Stack Gas, PAH	Dibenzo(a,h)anthracene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.005	ND< 0.005	ND< 0.004	ND< 0.005
Stack Gas, PAH	Benzo(g,h,i)perylene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.003	ND< 0.006	ND< 0.002	ND< 0.006
Stack Gas, PAH	2-Methylnaphthalene	HRGC/LRMS-SIM	ug/Nm3	0.071	0.078	0.028	0.059
Stack Gas, PAH	7,12-Dimethylbenz(a)anthracene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.019	ND< 0.022	ND< 0.023	ND< 0.023
Stack Gas, PAH	3-Methylcholanthrene	HRGC/LRMS-SIM	ug/Nm3	ND< 0.004	ND< 0.006	ND< 0.005	ND< 0.006

APPENDIX B
SITE 121 DATA USED IN CALCULATIONS

Stream	Substance	Method	UOM	Run 1	Run 2	Run 3	Average Used
Stack Gas, PCB	total Chlorobiphenyls	HRGC/LRMS-SIM	ug/Nm3	ND< 0.008	ND< 0.004	ND< 0.003	ND< 0.008
Stack Gas, PCB	total Dichlorobiphenyls	HRGC/LRMS-SIM	ug/Nm3	ND< 0.005	ND< 0.003	ND< 0.001	ND< 0.005
Stack Gas, PCB	total Trichlorobiphenyls	HRGC/LRMS-SIM	ug/Nm3	ND< 0.078	ND< 0.007	ND< 0.002	ND< 0.078
Stack Gas, PCB	total Tetrachlorobiphenyls	HRGC/LRMS-SIM	ug/Nm3	ND< 0.002	ND< 0.001	ND< 0.002	ND< 0.002
Stack Gas, PCB	total Pentachlorobiphenyls	HRGC/LRMS-SIM	ug/Nm3	ND< 0.005	ND< 0.004	ND< 0.004	ND< 0.005
Stack Gas, PCB	total Hexachlorobiphenyls	HRGC/LRMS-SIM	ug/Nm3	ND< 0.001	ND< 0.001	ND< 0.001	ND< 0.001
Stack Gas, PCB	total Heptachlorobiphenyls	HRGC/LRMS-SIM	ug/Nm3	ND< 0.002	ND< 0.002	ND< 0.002	ND< 0.002
Stack Gas, PCB	total Octachlorobiphenyls	HRGC/LRMS-SIM	ug/Nm3	ND< 0.001	ND< 0.001	ND< 0.001	ND< 0.001
Stack Gas, PCB	total Nonachlorobiphenyls	HRGC/LRMS-SIM	ug/Nm3	ND< 0.001	ND< 0.001	ND< 0.001	ND< 0.001
Stack Gas, PCB	Decachlorobiphenyl	HRGC/LRMS-SIM	ug/Nm3	ND< 0.004	ND< 0.003	ND< 0.002	ND< 0.004

Stream	Substance	Method	UOM	Run 3A	Run 3B	Run 3C	Average Used
Stack Gas, VOC	Benzene, Full Load	GC/MS	ug/Nm3	2.9	1.5@	1.3@	1.9
Stack Gas, VOC	Toluene, Full Load	GC/MS	ug/Nm3		18.4	17.8	18.1

Stream	Substance	Method	UOM	Run 3A	Run 3B	Run 3C	Average Used
Stack Gas, Aldehyde	Formaldehyde, Full Load	HPLC	ug/Nm3	7.0F	9.1F	7.8	8.0F

APPENDIX B
SITE 121 DATA USED IN CALCULATIONS

Stream	Substance	Method	UOM	Run #1 (IGAS 0913)	Run #2 (IGAS 0914)	Run #3 (IGAS 0915)	Average Used
N.G. Fuel, Non-hydrocarbons	Moisture	Hygrometer	ppmv				55
N.G. Fuel, Non-hydrocarbons	Oxygen	GC/TCD	ppmv				5.0
N.G. Fuel, Non-hydrocarbons	Helium	GC/TCD	mole %	0.025	0.022	0.023	0.023
N.G. Fuel, Non-hydrocarbons	Hydrogen	GC/TCD	mole %	0.003	0.002	0.002	0.002
N.G. Fuel, Non-hydrocarbons	Nitrogen	GC/TCD	mole %	0.50	0.52	0.46	0.49
N.G. Fuel, Non-hydrocarbons	Carbon Dioxide	GC/TCD	mole %	1.76	1.77	1.75	1.76
N.G. Fuel, Hydrocarbons	Methane	GC/FID	mole %	95.5	95.5	95.6	95.5
N.G. Fuel, Hydrocarbons	Ethane	GC/FID	mole %	1.69	1.67	1.68	1.68
N.G. Fuel, Hydrocarbons	Propane	GC/FID	mole %	0.351	0.348	0.0354	0.351
N.G. Fuel, Hydrocarbons	i-Butane	GC/FID	mole %	0.038	0.038	0.038	0.038
N.G. Fuel, Hydrocarbons	n-Butane	GC/FID	mole %	0.056	0.055	0.053	0.055
N.G. Fuel, Hydrocarbons	neo-Pentane	GC/FID	mole %				0.001@
N.G. Fuel, Hydrocarbons	i-Pentane	GC/FID	mole %	0.02	0.02	0.02	0.02
N.G. Fuel, Hydrocarbons	n-Pentane	GC/FID	mole %	0.02	0.02	0.02	0.02
N.G. Fuel, Hydrocarbons	C6 & Heavier	HRGC/FID	mole %	0.032	0.030	0.033	0.032

Stream	Substance	Method	UOM	Average Used
N.G. Fuel, Aliphatics	Cyclopentane	HRGC/FID	ppmv	6
N.G. Fuel, Aliphatics	Hexanes	HRGC/FID	ppmv	142
N.G. Fuel, Aliphatics	Methyl cyclopentane	HRGC/FID	ppmv	19
N.G. Fuel, Aliphatics	Cyclohexane	HRGC/FID	ppmv	26
N.G. Fuel, Aliphatics	Heptanes	HRGC/FID	ppmv	59
N.G. Fuel, Aliphatics	Methyl cyclohexane	HRGC/FID	ppmv	27
N.G. Fuel, Aliphatics	Octanes	HRGC/FID	ppmv	26
N.G. Fuel, Aliphatics	Nonanes	HRGC/FID	ppmv	13
N.G. Fuel, Aliphatics	Decanes	HRGC/FID	ppmv	4.1
N.G. Fuel, Aliphatics	Undecanes	HRGC/FID	ppmv	1.2
N.G. Fuel, Aliphatics	Dodecanes	HRGC/FID	ppmv	0.8
N.G. Fuel, Aliphatics	Tridecanes	HRGC/FID	ppmv	0.6
N.G. Fuel, Aliphatics	Tetradecanes	HRGC/FID	ppmv	0.40@

APPENDIX B
SITE 121 DATA USED IN CALCULATIONS

Stream	Substance	Method	UOM		Average Used
N.G. Fuel, Aromatics	Benzene	HRGC/FID	ppmv		7
N.G. Fuel, Aromatics	Toluene	HRGC/FID	ppmv		6
N.G. Fuel, Aromatics	Ethylbenzene	HRGC/FID	ppmv		0.5
N.G. Fuel, Aromatics	Xylenes	HRGC/FID	ppmv		3.2
N.G. Fuel, Aromatics	C3-benzenes	HRGC/FID	ppmv	ND<	0.1
N.G. Fuel, Aromatics	Naphthalenes	HRGC/FID	ppmv	ND<	0.1
N.G. Fuel, Aromatics	PAH	HPLC	ppmv	ND<	0.02

Stream	Substance	Method	UOM		Average Used
N.G. Fuel, Sulfur compounds	Hydrogen sulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Carbonyl sulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Carbon disulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Methyl mercaptan	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Ethyl mercaptan	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	i-Propyl mercaptan	GC/FPD/SCD	ppmv		0.02@
N.G. Fuel, Sulfur compounds	n-Propyl mercaptan	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	t-Butyl mercaptan	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Dimethyl sulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Methyl ethyl sulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Diethyl sulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Methyl ethyl disulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Diethyl disulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Methyl i-propyl disulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Ethyl i-propyl disulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Ethyl n-propyl disulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	i-Propyl n-propyl disulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Di-i-propyl disulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	i-Propyl t-butyl disulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Ethyl t-butyl disulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Di-t-butyl disulfide	GC/FPD/SCD	ppmv	ND<	0.02
N.G. Fuel, Sulfur compounds	Thiophane	GC/FPD/SCD	ppmv		0.03@
N.G. Fuel, Sulfur compounds	Other target compounds	GC/FPD/SCD	ppmv	ND<	0.02

Stream	Substance	Method	UOM		Average Used
N.G. Fuel, Halocarbons	35 target compounds	GC/ELCD	ppmv	ND<	0.1
N.G. Fuel, Halocarbons	PCB	GC/ECD	ppmv	ND<	0.01

APPENDIX B
SITE 121 DATA USED IN CALCULATIONS

Stream	Substance	Method	UOM		Average Used
N.G. Fuel, Nitrogen compounds	Ammonia	GC/AED	ppmv	ND<	4
N.G. Fuel, Nitrogen compounds	17 target compounds	GC/AED	ppmv	ND<	0.5

Stream	Substance	Method	UOM		Average Used
N.G. Fuel, Oxygenated compounds	Methanol	GC/AED	ppmv		21
N.G. Fuel, Oxygenated compounds	Acetaldehyde	GC/AED	ppmv	ND<	1
N.G. Fuel, Oxygenated compounds	Acetone	GC/AED	ppmv	ND<	1
N.G. Fuel, Oxygenated compounds	Other 14 target compounds	GC/AED	ppmv	ND<	1

Stream	Substance	Method	UOM		Average Used
N.G. Fuel, Elements/Compounds	Total Arsenic	GC/AED	ug/m^3		4@
N.G. Fuel, Elements/Compounds	Total Mercury	GC/AED	ug/m^3		0.02@
N.G. Fuel, Elements/Compounds	NO	Chemiluminescence	ppmv	ND<	0.1
N.G. Fuel, Elements/Compounds	NOx	IC	ppmv		1.2
N.G. Fuel, Elements/Compounds	Radon	Gamma-Spectroscopy	pCi/L		1@

Stream	Substance	Method	UOM		Average Used
N.G. Gas, Metals/Anion Precursors	Cobalt	GC-AED	ppmv	ND<	0.1
N.G. Gas, Metals/Anion Precursors	Copper	GC-AED	ppmv	ND<	0.05
N.G. Gas, Metals/Anion Precursors	Lead	GC-AED	ppmv	ND<	0.1
N.G. Gas, Metals/Anion Precursors	Nickel	GC-AED	ppmv	ND<	0.05
N.G. Gas, Metals/Anion Precursors	Selenium	GC-AED	ppmv	ND<	0.002
N.G. Gas, Metals/Anion Precursors	Phosphorus	GC-AED	ppmv	ND<	0.01
N.G. Gas, Metals/Anion Precursors	Chlorine	GC-AED	ppmv	ND<	0.2
N.G. Gas, Metals/Anion Precursors	Fluorine	GC-AED	ppmv	ND<	1
N.G. Gas, Metals/Anion Precursors	Bromine	GC-AED	ppmv	ND<	0.1
N.G. Gas, Metals/Anion Precursors	Other metals	GC-AED	ppmv		ND

APPENDIX C
DATA NOT USED IN CALCULATIONS

C-3

This appendix contains data that was not used in emissions or mass balance calculations. This appendix also contains the results of VOC tests conducted at other than full load conditions.

APPENDIX C

SITE 121 DATA NOT USED IN CALCULATIONS

Stream	Substance	Method	UOM		Run 2
Stack Gas, Metals	Arsenic	ICP-Hydride	ug/Nm3		0.22F
Stack Gas, Metals	Barium	ICP-AES	ug/Nm3		8.0
Stack Gas, Metals	Beryllium	ICP-AES	ug/Nm3	ND<	0.02
Stack Gas, Metals	Cadmium	ICP-AES	ug/Nm3	ND<	0.05
Stack Gas, Metals	Chromium	ICP-AES	ug/Nm3		118
Stack Gas, Metals	Cobalt	ICP-AES	ug/Nm3		0.94
Stack Gas, Metals	Copper	ICP-AES	ug/Nm3		147
Stack Gas, Metals	Lead	GFAAS	ug/Nm3		2.0
Stack Gas, Metals	Manganese	ICP-AES	ug/Nm3		13.9
Stack Gas, Metals	Mercury	CVAAS	ug/Nm3		0.38@
Stack Gas, Metals	Molybdenum	ICP-AES	ug/Nm3		3.6F
Stack Gas, Metals	Nickel	ICP-AES	ug/Nm3		65
Stack Gas, Metals	Selenium	ICP-Hydride	ug/Nm3	ND<	0.04
Stack Gas, Metals	Phosphorus	ICP-AES	ug/Nm3		6.9F
Stack Gas, Metals	Vanadium	ICP-AES	ug/Nm3		1.1

Stream	Substance	Method	UOM	Run 3A
Stack Gas, VOC	Toluene, Full Load	GC/MS	ug/Nm3	250

Stream	Substance	Method	UOM			Average Used
				Run 4A	Run 4B	
Stack Gas, VOC	Benzene, Min. Load, Normal O2	GC/MS	ug/Nm3	1.0@	1.7@	1.3@
Stack Gas, VOC	Toluene, Min. Load, Normal O2	GC/MS	ug/Nm3	3.2	3.8	3.5
				Run 5A	Run 5B	
Stack Gas, VOC	Benzene, Min. Load, Low O2	GC/MS	ug/Nm3	0.8@	1.1@	1.0@
Stack Gas, VOC	Toluene, Min. Load, Low O2	GC/MS	ug/Nm3	1.6@	3.2	2.4
				Run 6A	Run 6B	
Stack Gas, VOC	Benzene, Min. Load, High O2	GC/MS	ug/Nm3	1.6@		1.6@
Stack Gas, VOC	Toluene, Min. Load, High O2	GC/MS	ug/Nm3	3.2		3.2

APPENDIX C
SITE 121 DATA NOT USED IN CALCULATIONS

Stream	Substance	Method	UOM				Average Used
				Run 4A	Run 4B		
Stack Gas, Aldehyde	Formaldehyde, Min. Load, Normal	HPLC	ug/Nm3	7.2	6.7		7.0
				Run 5A	Run 5B		
Stack Gas, Aldehyde	Formaldehyde, Min. Load, Low O2	HPLC	ug/Nm3	6.3F	6.1F		6.2F
				Run 6A	Run 6B		
Stack Gas, Aldehyde	Formaldehyde, Min. Load, High O2	HPLC	ug/Nm3	5.8	10.4		8.1

Stream	Substance	Method	UOM				Average Used
				Run 3			
Stack Gas, VOC	Total Hydrocarbons (as CH4)	FID	ug/Nm3	265			266
				Run 4	Run 5	Run 6	
Stack Gas, VOC	Total Hydrocarbons (as CH4)	FID	ug/Nm3	129	67	72	--

APPENDIX D

PROCESS STREAM FLOW RATES AND CALCULATION PROCEDURES

5. To Calculate CO_2, % for Each Sample Train

   a. Given CEM results for O_2, % and CO_2, % at the outlet and the portable O_2 meter results at each sample train.

   b. $$Test\ CO_2 = CEM\ CO_2 \times \frac{20.9 - test\ O_2}{20.9 - CEM\ O_2}$$

6. To Construct a Mass Balance Around the Boiler for a Given Parameter, *i*

   a. Given fuel and flue gas results.

   b. Mass balance$_i$ = M_i (flue gas)/M_i (fuel), expressed as %

7. Nomenclature:

A_s	=	stack area, ft^2
B_{wo}	=	flue gas moisture content
C	=	particulate grain loading, gr/dscf
C_p	=	pitot calibration factor, dimensionless
D_n	=	nozzle diameter, in.
F	=	fuel F factor, dscf/10^6 Btu at 0% O_2
H	=	orifice pressure differential, iwg
I	=	% isokinetics
M_n	=	mass of collected particulate, mg
MW	=	molecular weight of flue gas
MW_i	=	molecular weight of species i:
		NO_x : 46
		CO : 28
		SO_x : 64
		HC : 16
θ	=	sample time, min.
ΔP	=	average velocity head, iwg = $\left(\overline{\sqrt{\Delta P}}\right)^2$
P_{bar}	=	barometric pressure, in.Hg
P_s	=	stack absolute pressure, in.Hg
P_{sg}	=	stack static pressure, iwg
Q	=	wet stack gas flow rate at actual conditions, wacfm
Q_{sd}	=	dry stack gas flow rate at standard conditions, dscfm

3. To Estimate Emissions Rates in lb/10^6 Btu Using EPA Method 19 and Given Fuel Analysis

a. Fuel factor at 68 °F, dscf/10^6 Btu at 0% O_2

$$F_{68} = \frac{10^6[3.64(\%H) + 1.53(\%C) + 0.14\ (\%N) + 0.57(\%S) - 0.46(\%O_2,fuel)]}{HHV,\ Btu/lb}$$

b. Fuel factor at 60 °F

$$F_{60} = F_{68}\left(\frac{520\ °R}{528\ °R}\right)$$

c. Gaseous Emissions factor, lb/10^6 Btu

$$\left(\frac{lb}{10^6\ Btu}\right)_i = (ppm)_i\ (10^{-6})\left(\frac{MW_i\ lb}{lb\ mole}\right)\left(\frac{1}{SV}\right)(F)\left(\frac{20.9}{20.9\ -\ \%O_2}\right)$$

d. Gaseous Emissions factor, lb/10^{12} Btu

$$\left(\frac{lb}{10^{12}\ Btu}\right)_i = \left(\frac{lb}{10^6\ Btu}\right)_i \times 10^6$$

e. Particulate emission factor, lb/10^6 Btu

$$\left(\frac{lb}{10^6\ Btu}\right) = C\left(\frac{1\ lb}{7000\ gr}\right)(F)\left(\frac{20.9}{20.9\ -\ \%O_2}\right)$$

f. Particulate emission factor, lb/10^{12} Btu

$$\left(\frac{lb}{10^{12}\ Btu}\right) = \left(\frac{lb}{10^6\ Btu}\right) \times 10^6$$

4. To Calculate Trace Species Emissions Given Laboratory Results

a. μg/sample train = (μg detected) - (μg in field or reagent blank)

b. $\mu g/dscm = \mu g$ sample train x $(35.31/V_{m\ std})$

c. $\mu g/Nm^3 = \mu g/dscm$ x 492 °F/T_{ref}

d. For Benzene and Toluene Results
$\mu g/Nm^3$ = ppb x (MW_i/SV) x (35.31/2.2) x (T_{ref}/492 °F) x 10^9

Notes: Laboratory results could be in μg, mg or ppb. PAH, metals, formaldehyde and nitrosamine results will be in μg, particulate and anion results will be in mg, and benzene and toluene results will be in ppb.

Field and reagent blank values must be evaluated before subtracting them. For example, very low blanks may merely indicate "noise" and might be disregarded. On the other hand, very high blank values may indicate sampling or analysis problems which should be investigated. It may be acceptable to use a blank correction on some projects or with some reference methods. Typically a reagent blank is a more appropriate indicator of blank levels than a field blank.

TABLE D-4
SAMPLE TRAIN CALCULATION PROCEDURES
SITE 121

1. To Calculate Sample Volume, Actual Exhaust Flow Rate and Isokinetics for Each Sample Train

   a. Sample gas volume, dscf

   $$V_{m\,std} = 0.03342\ V_m \left(P_{bar} + \frac{H}{13.6}\right)\left(\frac{T_{ref}}{T_m}\right)(Y)$$

   b. Water vapor volume, scf

   $$V_{w\,std} = 0.0472\ V_{lc}\left(\frac{T_{ref}}{528\ ^\circ R}\right)$$

   c. Moisture content, nondimensional

   $$B_{wo} = \frac{V_{w\,std}}{V_{m\,std} + V_{w\,std}}$$

   d. Stack gas molecular weight, lb/lb mole

   $$MW_{dry} = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2)$$

   $$MW_{wet} = MW_{dry}\ (1 - B_{wo}) + 18\ (B_{wo})$$

   e. Absolute stack pressure, in Hg

   $$P_s = P_{bar} + \frac{P_{sg}}{13.6}$$

   f. Stack velocity, ft/sec

   $$V_s = 2.90\ C_p\ \sqrt{\Delta P T_s}\ \sqrt{\left(\frac{29.92}{P_s}\right)\left(\frac{28.95}{MW_{wet}}\right)}$$

   g. Actual stack flow rate, wacfm

   $$Q = (V_s)(A_s)(60)$$

   h. Standard stack gas flow rate, dscfm

   $$Q_{std} = Q\ (1 - B_{wo})\left(\frac{T_{ref}}{T_s}\right)\left(\frac{P_s}{29.92}\right)$$

   i. Percent isokinetic

   $$I = \left(\frac{17.32(T_s)(V_{m\,std})}{(1 - B_{wo})(\Theta)(V_s)(P_s)(D_n^2)}\right)\left(\frac{528\ ^\circ R}{T_{ref}}\right)$$

2. To Calculate Particulate Emissions

   a. Grain loading, gr/dscf

   $$C = 0.01543\left(\frac{M_n}{V_{m\,std}}\right)$$

TABLE D-3 (continued)
SAMPLE TRAIN TEST SUMMARY
SITE 121

	FORMALDEHYDE	
PARAMETER	BASE LOAD	MINIMUM LOAD
Date	4/14/93	4/15/93
Test Number	3A-FORM	4A-FORM
Std. Sample Volume, dscf	4.55	4.36
Std. Sample Volume, Nm^3	0.120	0.115
O_2, %	6.63(1)	7.55(2)
Date	4/14/93	4/15/93
Test Number	3B-FORM	4B-FORM
Std. Sample Volume, dscf	4.58	4.30
Std. Sample Volume, Nm^3	0.121	0.113
O_2, %	6.63(1)	7.55(2)
Date	4/14/93	4/15/93
Test Number	3C-FORM	5A-FORM
Std. Sample Volume, dscf	4.51	4.28
Std. Sample Volume, Nm^3	0.119	0.113
O_2, %	6.63(1)	6.25(2)
Date		4/15/93
Test Number		5B-FORM
Std. Sample Volume, dscf		4.38
Std. Sample Volume, Nm^3		0.116
O_2, %		6.25(2)
Date		4/15/93
Test Number		6A-FORM
Std. Sample Volume, dscf		4.34
Std. Sample Volume, Nm^3		0.114
O_2, %		7.50(2)
Date		4/15/93
Test Number		6B-FORM
Std. Sample Volume, dscf		4.47
Std. Sample Volume, Nm^3		0.118
O_2, %		7.50(2)

(1) O_2 from concurrent isokinetic tests 3-PAH and 3-MTLS.
(2) O_2 from Tedlar bag oxygen measurement.

TABLE D-3 (continued)
SAMPLE TRAIN TEST SUMMARY
SITE 121

PARAMETER	BENZENE AND TOLUENE BASE LOAD	MINIMUM LOAD
Date	4/14/93	4/15/93
Test Number	3A-VOC	4A-VOC
O_2, %	6.68[1]	7.55[2]
Date	4/14/93	4/15/93
Test Number	3B-VOC	4B-VOC
O_2, %	6.68[1]	7.55[2]
Date	4/14/93	4/15/93
Test Number	3C-VOC	5A-VOC
O_2, %	6.63[1]	6.25[2]
Date		4/15/93
Test Number		5B-VOC
O_2, %		6.25[2]
Date		4/15/93
Test Number		6A-VOC
O_2, %		7.50[2]
Date		4/15/93
Test Number		6B-VOC
O_2, %		7.50[2]

(1) O_2 from concurrent isokinetic tests 3-PAH and 3-MTLS.
(2) O_2 from Tedlar bag oxygen measurement.

(continued)

TABLE D-3 (continued)
SAMPLE TRAIN TEST SUMMARY
SITE 121

PARAMETER	PAH/PCB
Date	4/12/93
Test Number	1-PAH
Std. Sample Volume, dscf	218.683
Std. Sample Volume, Nm^3	5.770
Moisture Fraction	0.152
Stack Gas Molecular Weight	27.82
Stack Gas Velocity, ft/sec	53.50
Stack Flow Rate, wacfm	1,111,816
Stack Flow Rate, dscfm	679,101
Isokinetic Ratio, %	101.95
Date	4/13/93
Test Number	2-PAH
Std. Sample Volume, dscf	204.666
Std. Sample Volume, Nm^3	5.400
Moisture Fraction	0.148
Stack Gas Molecular Weight	27.87
Stack Gas Velocity, ft/sec	52.28
Stack Flow Rate, wacfm	1,086,462
Stack Flow Rate, dscfm	660,129
Isokinetic Ratio, %	98.16
Date	4/14/93
Test Number	3-PAH
Std. Sample Volume, dscf	214.071
Std. Sample Volume, Nm^3	5.648
Moisture Fraction	0.156
Stack Gas Molecular Weight	27.76
Stack Gas Velocity, ft/sec	53.45
Stack Flow Rate, wacfm	1,116,777
Stack Flow Rate, dscfm	679,009
Isokinetic Ratio, %	99.82

TABLE D-3
SAMPLE TRAIN TEST SUMMARY
SITE 121

PARAMETER	MULTI-METALS
Date	4/12/93
Test Number	1-MTLS
Std. Sample Volume, dscf	251.167
Std. Sample Volume, Nm^3	6.627
Moisture Fraction	0.153
Stack Gas Molecular Weight	27.81
Stack Gas Velocity, ft/sec	53.39
Stack Flow Rate, wacfm	1,109,530
Stack Flow Rate, dscfm	677,413
Isokinetic Ratio, %	98.99
Date	4/13/93
Test Number	2-MTLS
Std. Sample Volume, dscf	240.634
Std. Sample Volume, Nm^3	6.349
Moisture Fraction	0.147
Stack Gas Molecular Weight	27.88
Stack Gas Velocity, ft/sec	51.87
Stack Flow Rate, wacfm	1,077,942
Stack Flow Rate, dscfm	657,796
Isokinetic Ratio, %	97.67
Date	4/14/93
Test Number	3-MTLS
Std. Sample Volume, dscf	258.133
Std. Sample Volume, Nm^3	6.811
Moisture Fraction	0.148
Stack Gas Molecular Weight	27.83
Stack Gas Velocity, ft/sec	52.265
Stack Flow Rate, wacfm	1,086,046
Stack Flow Rate, dscfm	667,612
Isokinetic Ratio, %	103.23

TABLE D-2
SUMMARY OF EXHAUST GAS CONDITIONS AND FLOW RATES FOR ISOKINETIC TESTS
SITE 121

Test No.	Date	Time	O_2, %[1]	CO_2, %[2]	H_2O, %	Stack Temp., °F	V_{mstd}, dscf	Gross Load, MW	Flow Rate[3] (Pitot) dscfm	Flow Rate[4] (F-factor) dscfm	Isokinetic Ratio, %
1-PAH	04/12/93	1350/2030	6.13	8.39	15.2	270	218,683	334	679,101	622,506	102.0
1-MTLS	04/12/93	1345/2030	6.15	8.37	15.3	270	251,167	334	677,413	623,519	99.0
2-PAH	04/13/93	0905/1525	6.04	8.37	14.8	278	204,666	334	660,129	619,456	98.2
2-MTLS	04/13/93	0905/1530	6.09	8.34	14.7	275	240,634	334	675,796	621,548	97.7
3-PAH	04/14/93	0845/1500	6.43	8.19	15.6	266	214,071	334	678,251	637,057	99.9
3-MTLS	04/14/93	0845/1505	6.83	7.96	14.8	269	258,133	334	666,878	655,214	103.3
Average Outlet			6.28	8.27	15.1	271			672,928	629,883	
Standard Deviation Outlet			0.30	0.17	0.4	4.4			7,684	13,901	

NA = Not applicable

Notes:

(1) Test O_2 for metals and PAH tests taken from portable O_2 meter.

(2) CO_2 calculated from APH inlet CEM values corrected to test O_2.

(3) Pitot measured flow rates are from isokinetic tests for Runs 1-3.

(4) F-factor flow rate calculated using:
dscfm=Fuel flow, kscfh*HHV, Btu/scf*F-factor @ 0% O_2, dscf/MMBtu*10^6*20.9/(20.9-O_2(test))*hr/60 min*1000

TABLE D-1
MEAN PROCESS STREAM FLOWS
SITE 121

Stream	Mean Flow Rate	Standard Deviation	Source
Natural Gas, kscfh at 68°F			
Base Load	3,072	3.6	Measured[1]
Minimum Load	1,240	7.0	Measured[1]
Flue Gas, dscfm			
Base Load	632,187	14,078	Calculated[2]
Minimum Load	269,889	14,910	Calculated[3]

(1) Measured from plant fuel flow instrumentation.
(2) Calculated from and fuel F-factor and fuel flows for Runs 1, 2 and 3.
(3) Calculated from fuel F-factor and fuel flows for Runs 4, 5 and 6.

The tables in Appendix D summarize the following information for Site 121:

D-1	Mean Process Stream Flows
D-2	Flue Gas Conditions and Flow Rates for Isokinetic Tests
D-3	Sample Train Test Summaries
D-4	Emission Calculations

SV	=	specific molar volume of an ideal gas at standard conditions, ft^3/lb mole
T_m	=	meter temperature, °R
T_{ref}	=	reference temperature, °R
T_s	=	stack temperature, °R
V_s	=	stack velocity, ft/sec
V_{lc}	=	volume of liquid collected in impingers, ml
V_m	=	dry meter volume uncorrected, dcf
$V_{m\ std}$	=	dry meter volume at standard conditions, dscf
$V_{w\ std}$	=	volume of water vapor at standard conditions, scf
Y	=	meter calibration coefficient

APPENDIX E
PROCESS OPERATION

SUMMARY OF BOILER OPERATING CONDITIONS
SITE 121

Test No.	1	2	3	4	5	6
Date	4/12/93	4/13/93	4/14/93	4/16/93	4/16/93	4/16/93
Test Condition	Full Load Baseline	Full Load Baseline	Full Load Baseline	Min. Load Normal O_2	Min. Load Low O_2	Min. Load High O_2
Gross MW	333.6	334.0	334.2	122.7	122.5	122.4
Net MW	326.1	326.4	326.6	118.7	118.7	118.3
BOOS	1-8C, 5B, 6B	1-8C, 5B, 6B	1-8C, 5B, 6B	1-8C	1-8C	1-8C
FGR Level	Normal	Normal	Normal	Normal	Normal	Normal
Overfire Air	Open	Open	Open	Open	Open	Open
Main Stream, Klb/hr	2000	2000	2000	760	750	750
Air Flow, %	97	96	97	40	36	44
Fuel Flow, %	90	89	90	36	35	36
O_2, % A side[4]	2.7	2.5	2.7	4.4	2.6	5.3
O_2, % B side[4]	1.9	1.9	2.2	5.2	3.0	6.6
SH Spray, Klb/hr	39	38	41	0	0	0
RH Spray, Klb/hr	129	130	130	0	0	0
FD Fan A, amps	306	307	304	40	--	20
FD Fan B, amps	304	303	304	0	--	20
GR Fan A, amps	66	70	68	80	80	84
GR Fan B, amps	69	72	70	83	83	86
Opacity, %[1]	<2	<2	<2	<2	3-8%	0
CO, ppm chart[1]	50-200	50-200	50-200	0	0	0
O_2, %[2]	2.74	2.69	2.70	3.71	2.69	5.12
NO_x @ 3% O_2[2]	102	100	97.0	56.1	46.4	77.7
CO, ppm @ 3% O_2[2]	91	70	98	7	9	10
Fuel Flow, Kscfh	3,022	3,024	3,029	1,218	1,216	1,229
Heat Rate, Btu/KW-hr	9,592	9,593	9,601	10,620	10,614	10,766
Boiler Exit Flow Rate, dscfm[3]	500,500	502,800	503,600	212,900	200,100	241,700
NO_x, lb/MW-hr[2]	1.19	1.17	1.13	0.72	0.60	1.02
NO_x, lb/10^6 Btu[2]	0.13	0.13	0.12	0.071	0.059	0.09
CO, lb/MW-hr[2]	0.62	0.47	0.66	0.05	0.07	0.08

Notes:

(1) CO and opacity taken from conrol room strip chart.

(2) NO_x, O_2, and CO taken from hourly logs of plant CEM located near the boiler exit.

(3) Flue gas flow rate calculated from the fuel flow using the F-factor corrected to the measured O_2, % at the APH inlet.

(4) A and B side O_2 readings are control room readings of economizer exit gas.

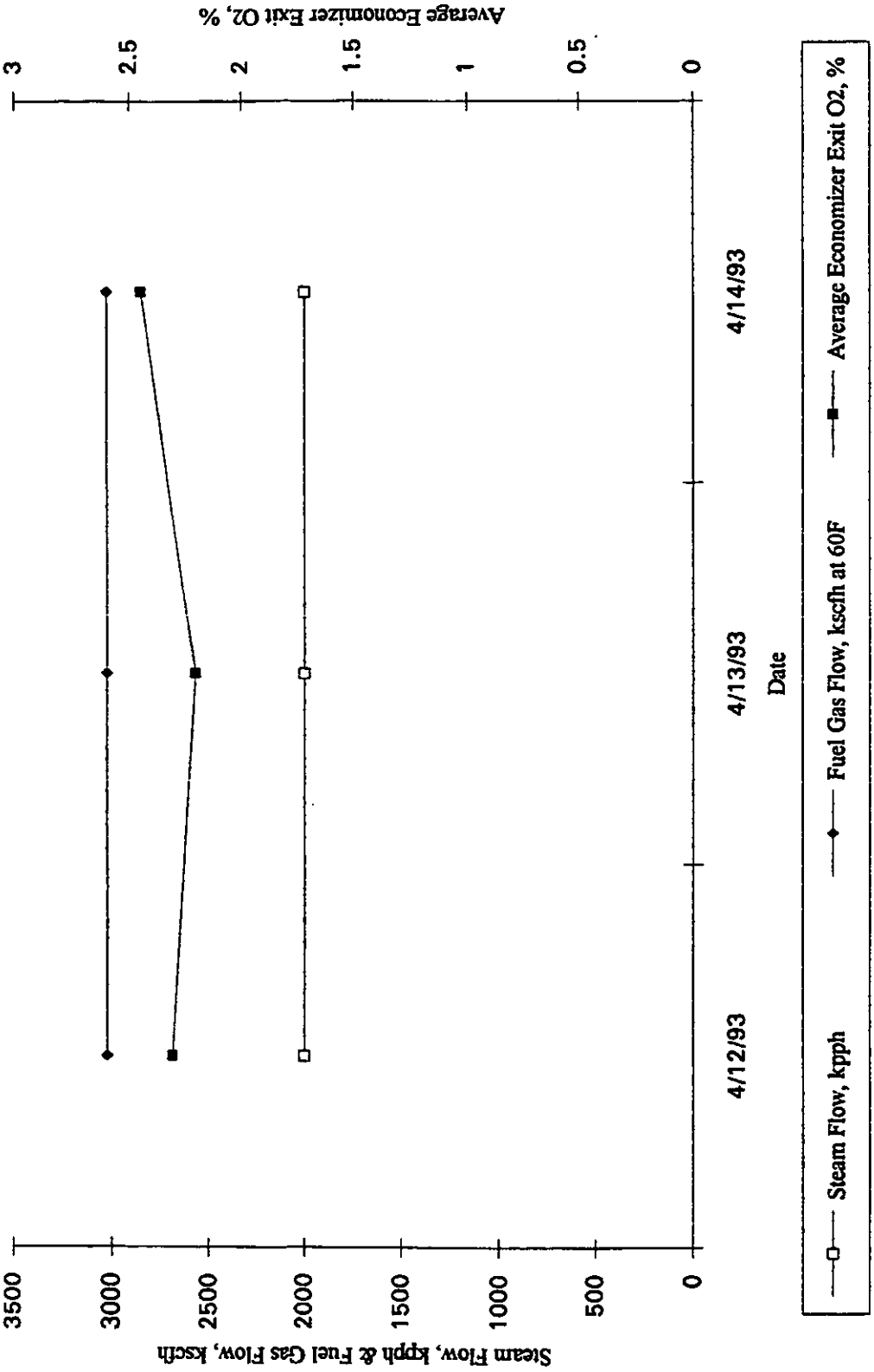

Figure E-1. Unit Operating Conditons, Site 121

APPENDIX F
UNCERTAINTY ANALYSIS

Because the data generated in this program may be used in conducting risk assessments and in making policy and regulatory decisions, consideration of the uncertainties in the results generated in the program are important. Assessment of the uncertainty level of a measurement is especially important when the measured results are near the detection level of the methods.

In calculating uncertainties that are presented in this report, procedures were followed that have been previously established for PISCES data treatment. This procedure involved calculating an overall uncertainty for each result using standard statistical techniques and known measurement biases. An error propagation analysis was performed on calculated results to determine the contribution of process, sampling and analytical variability, and measurement bias, to the overall uncertainty in the result. This uncertainty was determined by propagating the bias and precision error of individual parameters in the calculation of the results.

This uncertainty does not represent the total uncertainty in the result since many important bias errors are unknown and have been assigned a value of zero for this analysis. This uncertainty is only the uncertainty in the result for the period of time that the measurements were taken and does not represent long-term process variations. In addition, the following calculations assume that the population distribution of each measurement is normally distributed and that the samples collected reflect the true population.

The method described below is based on ANSI/ASME PTC 19.1-1985, "Measurement Uncertainty."

Nomenclature

r = Calculated result;
S_{pi} = Sample standard deviation of parameter i;
$S_{\overline{pi}}$ = Standard deviation of the average of parameter i;
Θ_i = Sensitivity of the result to parameter i;
B_{pi} = Bias error estimate for parameter i;
ν_i = Degrees of freedom in parameter i;
ν_r = Degrees of freedom in result;
S_r = Precision component of result uncertainty;
B_r = Bias component of result uncertainty;
t = Student "t" factor (two-tailed distribution at 95%);
U_r = Uncertainty in r;
P_i = Parameter i;
ΔP_i = Perturbation in parameter i;
N_i = Number of measurements of parameter i; and
E = Emission rate

For a result, r, the uncertainty in r is calculated as:

$$U_r = \sqrt{B_r^2 + (S_r * t)^2}$$

The components are calculated by combining the errors in the parameters used in the result calculation.

$$B_r = \sqrt{\sum_{i=1}^{j} (\theta_i * B_{pi})^2}$$

$$S_r = \sqrt{\sum_{i=1}^{j} (\theta_i * S_{\overline{pi}})^2}$$

The sensitivity of the result to each parameter is found from a Taylor series estimation method:

$$\theta_1 = \frac{\partial r}{\partial pi}$$

Or using a perturbation method (useful in computer applications):

$$\theta_i = \frac{r(P_i + \Delta P_i) - r(P_i)}{\Delta P_i}$$

The standard deviation of the average for each parameter is calculated as:

$$S_{\overline{pi}} = \frac{S_{pi}}{\sqrt{N_i}}$$

The degrees of freedom for each parameter is found from

$$\nu_i = N_i - 1$$

and the degrees of freedom for the result is found be weighing the sensitivity and precision error in each parameter.

$$\nu_r = \frac{S_r^4}{\sum_{i=1}^{j} \left[\frac{(S_{\overline{pi}} * \theta_i)^4}{\nu_i} \right]}$$

The Student "t" in the first equation is associated with the degrees of freedom in the result.

The precision error terms are generated using collected data, and assigning degrees of freedom to each parameter. Bias errors are more qualitative in nature. Bias values are assigned based on observation of the process and engineering judgment.

For this report the following sources of bias were considered:

- No bias was assigned to analytical results unless the result is less than the detection limit. Then one-half the detection limit is used for both the parameter value and its bias in calculations.

  This bias component for results below the reporting limit is calculated as:

$$B_{pi} = \sqrt{\sum_{i=1}^{N_i} \left(B_i * \frac{1}{N_i} \right)^2}$$

- The nonaxial nature of the gas flow at the stack resulted in measured velocities by the S-type pitot probes that were up to 8.3% higher than flow rates calculated from fuel flow rate and stoichiometric calculations. During all isokinetic tests, sample flow rate was set based on the faster velocity measured by the pitot probe, as specified in EPA Methods 1, 2 and 5. This means that "true" isokinetic sampling rates may have been up to 8.3% low. Estimating errors introduced by nonisokinetic sampling, this would correspond to an uncertainty of up to 8.3% in the concentrations of particulate species. As a conservative estimate, an uncertainty of 10% was applied to all particulate species measured from isokinetic tests.

- No uncertainty was assumed due to long term process variations.

In interpreting and understanding the uncertainty values, it should be pointed out that when two levels of uncertainty are combined using a root-sum-squared process, the larger uncertainty predominates. A few examples are presented below:

- Combining two uncertainties of 10% results in a total uncertainty of 14%.

- Combining uncertainties of 50% and 8% results in a total uncertainty of 51%.

- Combining uncertainties of 90% and 10% results in an uncertainty of 90.5%.

Confidence Interval Calculations

In this report the confidence interval as a percent uncertainty is reported with the sample results. The uncertainty values calculated for this report are based on the 95% confidence interval calculated for emission factors of the target species. This confidence interval equation propagates the error associated with the parameters required to determine concentration, mass emissions, and emission factors. The uncertainty is then expressed as a percentage so that it may be applied to an average result expressed in the required units.

Emission factors are calculated in units of lb/10^{12} Btu. However, the equations used for uncertainty calculations are in mass emission units of lb/hr since these equations allow for an estimate of overall uncertainty incorporating all relevant parameters.

The following are sample calculations for the 95% confidence interval around the mean for air and fuel samples. This procedure utilized the same method outlined earlier in this section and used in the computer program.

FLUE GAS

$$E,\ lb/hr = Concentration,\ \frac{\mu g}{Nm^3} \times Heat\ Rate,\ \frac{Btu}{MW-hr} \times F-Factor,\ \frac{dscf}{MMBtu} \times \frac{20.9}{20.9 - O_2(test),\%} \times Load,\ MW \times 5.8127 \times 10^{-17},$$

where

$$Heat\ Rate, \frac{Btu}{MW-hr} = HHV\ of\ fuel,\ Btu/lb \times Fuel\ Flow,\ lb/hr \div Load,\ MW$$

FUEL

$$E,\ lb/hr = Concentration,\ \frac{mg}{kg} \times Heat\ Rate,\ \frac{Btu}{MW-hr} \times 10^{-6} \times Load,\ MW \times \frac{1}{HHV,\ Btu/lb}$$

The following example calculation shows how the overall uncertainty of the stack naphthalene value from this program was determined.

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	$\mu g/Nm^3$	1.20	2.22	1.36	1.59
Heat Rate	Btu/MW-hr	9.40×10^6	9.39×10^6	9.40×10^6	9.40×10^6
F-Factor	dscf/MMBtu	8615	8619	8622	8618
O_2 (test)	%	6.13	6.04	6.43	6.20
Load (net)	MW	326	326	327	326

The sensitivity of each variable is calculated with a perturbation for each parameter that is equal to the larger value of the standard deviation of the average, $S_{\bar{p}i}$, or the bias error, B_{pi}. For the concentration variable:

$$S_{\overline{pc}} = \frac{S_{pi}}{\sqrt{N_i}} = \frac{0.549}{\sqrt{3}} = 0.317$$

$$E_{(c = 1.59)} = 1.59 \times 9.40 \times 10^6 \times 8618 \times \frac{20.9}{20.9 - 6.20} \times 326 \times 5.8127 \times 10^{-17} = 3.47 \times 10^{-3}$$

$$E_{(c = 1.91)} = 50.1 \times 9.40 \times 10^6 \times 8618 \times \frac{20.9}{20.9 - 6.20} \times 326 \times 5.8127 \times 10^{-17} = 4.16 \times 10^{3}$$

$$\theta_c = \frac{E_{(Pi + \Delta Pi)} - E_{Pi}}{\Delta P_i} = \frac{E_{(c=1.91)} - E_{(c=1.59)}}{0.317}$$

$$\theta_c = \frac{4.16 \times 10^{-3} - 3.47 \times 10^{-3}}{0.317} = 2.18 \times 10^{-3}$$

Similar calculations for each parameter produce the following results:

	PARAMETER		
	Concentration, $\mu g/Nm^3$	Heat Rate, Btu/MW-hr	F-Factor, dscf/MMBtu
Mean	1.59	9.40×10^6	8618
S_{pi}	0.549	5.77×10^3	3.5
$S_{\overline{pi}}$	0.317	3.33×10^3	2.0
N_i	3	3	3
B_{pi}*	0.159	0	0
Θ_i	2.2×10^{-3}	3.7×10^{-10}	4.0×10^{-7}
ν_i	2	2	2
ΔP_i	0.317	3.33×10^3	2.0

Notes: The bias estimate for concentration includes no bias for analytical results and a 10% collection bias.

The precision and bias components are then calculated by root-sum-squaring the product of the parameter $S_{\overline{pi}}$ or B_{pi} and the sensitivity:

$$S_r = \sqrt{(\theta_c * S_{\overline{pc}})^2 + (\theta_{hr} * S_{\overline{phr}})^2 + (\theta_{ff} * S_{\overline{pff}})^2}$$

$$S_r = 6.9 \times 10^{-4}$$

$$B_r = \sqrt{(\theta_c * B_{pc})^2 + (\theta_{hr} * B_{phr})^2 + (\theta_{ff} * B_{pff})^2}$$

$$B_r = 3.5 \times 10^{-4}$$

The Student "t" factor for two degrees of freedom and a 95% confidence interval is 4.3.

The uncertainty in the result is then

$$U_r = \sqrt{B_r^2 = (S_r * t)^2} = \sqrt{(3.5 \times 10^{-4})^2 + (6.9 \times 10^{-4} \times 4.3)^2} = 2.99 \times 10^{-3}$$

The overall emission rate is reported as

$3.47 \times 10^{-3} \pm 2.99 \times 10^{-3}$ lb/hr or 86% uncertainty.

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SPECIES	LOC	RUN #1	RUN #3	RUN #2	AVERAGE (r)	SAMPLE STD. DEV. (Spl)	% SAMPLE RND ERR (Sr,%)	SAMPLE % BIAS (Br,%)	% UNCERT. (Ur,%)	ABSOL. VALUE	ABSOL. UNCERT. (Ur)	% RPDM	% CONTRIB OF ND, TO AVG
		in ug/Nm3								in lb/hr			
ARSENIC	OUT	0.24	0.31		2.75E-01	4.73E-02	154.6%	10.0%	154.9%	6.1E-04	9.4E-04	24.34%	0.0%
BARIUM		9.7	6.11		7.93E+00	2.57E+00	291.7%	10.0%	291.9%	1.8E-02	5.1E-02	45.91%	0.0%
BERYLLIUM	ND<	0.02	ND< 0.01	ND<	1.49E-02	2.88E-04	17.4%	25.6%	30.9%	ND< 3.3E-05	1.0E-05	2.74%	100.0%
CADMIUM		0.11	ND< 0.04		6.38E-02	5.91E-02	832.2%	15.2%	832.3%	1.4E-04	1.2E-03	96.48%	17.3%
CHROMIUM		2.1	0.90		1.50E+00	8.60E-01	514.0%	10.0%	514.1%	3.3E-03	1.7E-02	80.91%	0.0%
COBALT	ND<	0.15	ND< 0.15	ND<	1.49E-01	2.88E-03	17.4%	25.6%	30.9%	ND< 3.3E-04	1.0E-04	2.74%	100.0%
COPPER		2.1	1.16		1.63E+00	6.63E-01	365.7%	10.0%	365.8%	3.6E-03	1.3E-02	57.56%	0.0%
LEAD		0.81	0.79		8.04E-01	1.55E-02	17.4%	10.0%	20.1%	1.8E-03	3.6E-04	2.74%	0.0%
MANGANESE		0.61	0.54		6.11E-01	9.60E-02	141.2%	10.0%	141.5%	1.4E-03	1.9E-03	22.22%	0.0%
MERCURY	ND<	0.42	ND< 0.54	ND<	4.83E-01	8.54E-02	158.9%	25.8%	160.9%	ND< 1.1E-03	1.7E-03	25.00%	100.0%
MOLYBDENUM		2.7	2.50		2.61E+00	1.56E-01	53.7%	10.0%	54.6%	5.8E-03	3.1E-03	8.45%	0.0%
NICKEL		2.1	1.17		1.64E+00	6.63E-01	362.6%	10.0%	362.7%	3.6E-03	1.3E-02	57.07%	0.0%
SELENIUM	ND<	0.04	ND< 0.04	ND<	4.17E-02	8.06E-04	17.4%	25.6%	30.9%	ND< 9.2E-05	2.8E-05	2.74%	100.0%
PHOSPHORUS		5.9	6.75		6.32E+00	6.14E-01	87.4%	10.0%	87.9%	1.4E-02	1.2E-02	13.75%	0.0%
VANADIUM		0.71	0.57		6.41E-01	9.66E-02	135.4%	10.0%	135.8%	1.4E-03	1.9E-03	21.31%	0.0%
						AVERAGES:	211.1%	14.5%	214.4%	3.64E-03	7.9E-03	30.93%	

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PARAMETER	RUN #1	RUN #2	RUN #3	AVERAGE	STD DEV (Spi)	%STDEV (Spi,%)	N STDEV (Spi')	% BIAS (Bpi,%)	BIAS (Bpi)
METALS STK:									
F-factor, dscf/mmBtu	8,615	8,619	8,622	8,618	3.39	0.04%	1.96	0.00%	0.00
HHV, Btu/scf @68F	999	999	998	999	0.19	0.02%	0.11	0.00%	0.00
FUEL FLOW, kscfhr@68F	3,069	3,071	3,076	3,072	4	0.12%	2	0.00%	NA
UNIT LOAD, net MW	326	326	327	326	0.25	0.08%	0.15	0.00%	0.00
HEAT RATE, Btu/MWhr	9.40E+06	9.40E+06	9.40E+06	9.40E+06	2.53E+03	0.03%	1.46E+03	0.00%	0.00E+00
%O2	6.15	6.09	6.83	6.36	0.41	6.47%	0.24	0.00%	0.00
O2 Correction Factor	1.417	1.411	1.485	1.438	0.04	2.87%	0.02	0.00%	0.00
Particle Collection Bias								10%	

FREEDOM	T-VALUE
1	12.71
2	4.30
3	3.18
4	2.78
5	2.57
6	2.45
7	2.37
8	2.31

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RPDM FOR MIXED	RPDM ALL ND	CONC. DELTA P DETERMINATION NORM. STD DEV (Spc')	ND BIAS (Bpc1)	> OF NSTD OR BIAS	Particle Coll. Eff. Bias (Bpc2)	THETA CALCULATIONS FOR: CONC. (THETAc)	HEAT RT (THETAhr)	F-factor (THETAff)	RESULTS: Sr	Br	xr	xr	t-	Ur	% Ur
24.34%	24.34%	3.34E-02	0.00E+00	NSTDV	2.75E-02	2.2E-03	6.5E-11	7.0E-08	7.4E-05	6.1E-05	1.00	1	12.7	9.4E-04	154.9%
45.91%	45.91%	1.82E+00	0.00E+00	NSTDV	7.93E-01	2.2E-03	1.9E-09	2.0E-06	4.0E-03	1.8E-03	1.00	1	12.7	5.1E-02	291.9%
2.74%	2.74%	2.04E-04	3.51E-03	**BIAS**	1.49E-03	2.2E-03	3.5E-12	3.8E-09	4.5E-07	8.4E-06	1.00	1	12.7	1.0E-05	30.9%
96.48%	96.48%	4.18E-02	7.34E-03	NSTDV	6.38E-03	2.2E-03	1.5E-11	1.6E-08	9.2E-05	2.1E-05	1.00	1	12.7	1.2E-03	832.3%
80.91%	80.91%	6.03E-01	0.00E+00	NSTDV	1.50E-01	2.2E-03	3.5E-10	3.9E-07	1.3E-03	3.3E-04	1.00	1	12.7	1.7E-02	514.1%
2.74%	2.74%	2.04E-03	3.51E-02	**BIAS**	1.49E-02	2.2E-03	3.5E-11	3.8E-08	4.5E-06	8.4E-05	1.00	1	12.7	1.0E-04	30.9%
57.56%	57.56%	4.69E-01	0.00E+00	NSTDV	1.63E-01	2.2E-03	3.8E-10	4.2E-07	1.0E-03	3.6E-04	1.00	1	12.7	1.3E-02	365.8%
2.74%	2.74%	1.10E-02	0.00E+00	**BIAS**	8.04E-02	2.2E-03	1.9E-10	2.1E-07	2.4E-05	1.8E-04	1.00	1	12.7	3.6E-04	20.1%
22.22%	22.22%	6.79E-02	0.00E+00	NSTDV	6.11E-02	2.2E-03	1.4E-10	1.6E-07	1.5E-04	1.4E-04	1.00	1	12.7	1.9E-03	141.5%
25.00%	25.00%	6.04E-02	1.15E-01	**BIAS**	4.83E-02	2.2E-03	1.1E-10	1.2E-07	1.3E-04	2.7E-04	1.00	1	12.7	1.7E-03	160.9%
8.45%	8.45%	1.10E-01	0.00E+00	**BIAS**	2.61E-01	2.2E-03	6.1E-10	6.7E-07	2.4E-04	5.8E-04	1.00	1	12.7	3.1E-03	54.6%
57.07%	57.07%	4.69E-01	0.00E+00	NSTDV	1.64E-01	2.2E-03	3.9E-10	4.2E-07	1.0E-03	3.6E-04	1.00	1	12.7	1.3E-02	362.7%
2.74%	2.74%	5.70E-04	9.82E-03	**BIAS**	4.17E-03	2.2E-03	9.8E-12	1.1E-08	1.3E-06	2.4E-05	1.00	1	12.7	2.8E-05	30.9%
13.75%	13.75%	4.34E-01	0.00E+00	**BIAS**	6.32E-01	2.2E-03	1.5E-09	1.6E-06	9.6E-04	1.4E-03	1.00	1	12.7	1.2E-02	87.9%
21.31%	21.31%	6.83E-02	0.00E+00	NSTDV	6.41E-02	2.2E-03	1.5E-10	1.6E-07	1.5E-04	1.4E-04	1.00	1	12.7	1.9E-03	135.8%
															214.4%

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SPECIES	LOC	RUN #1		RUN #2		RUN #3		AVERAGE (r)	SAMPLE STD. DEV. (Spl)	% SAMPLE RND ERR (Sr,%)	SAMPLE % BIAS (Br,%)	% UNCERT. (Ur,%)		ABSOL. VALUE	ABSOL. UNCERT. (Ur)	% RPDM	% CONTRIB OF ND, TO AVG
				In ug/Nm3										In lb/hr			
Naphthalene	OUT		1.20		2.22		1.36	1.59E+00	5.51E-01	85.8%	10.0%	86.4%		3.5E-03	3.0E-03	26.29%	0.0%
Acenaphthylene		ND<	0.014	ND<	0.004	ND<	0.006	7.93E-03	5.19E-03	162.5%	34.2%	166.1%	ND<	1.7E-05	2.9E-05	49.90%	100.0%
Acenaphthene		ND<	0.011	ND<	0.006	ND<	0.003	6.62E-03	3.72E-03	139.5%	33.3%	143.4%	ND<	1.4E-05	2.1E-05	39.75%	100.0%
Fluorene		ND<	0.026	ND<	0.013	ND<	0.010	1.64E-02	8.39E-03	127.0%	32.8%	131.2%	ND<	3.6E-05	4.7E-05	38.97%	100.0%
Phenanthrene			0.054	ND<	0.015	ND<	0.010	2.20E-02	2.75E-02	310.6%	16.7%	311.0%		4.8E-05	1.5E-04	96.14%	18.6%
Anthracene		ND<	0.040	ND<	0.010	ND<	0.005	1.85E-02	1.86E-02	250.1%	38.7%	253.1%	ND<	4.0E-05	1.0E-04	76.89%	100.0%
Fluoranthene		ND<	0.011	ND<	0.005	ND<	0.002	6.25E-03	4.58E-03	181.9%	35.1%	185.2%	ND<	1.4E-05	2.5E-05	53.48%	100.0%
Pyrene		ND<	0.013	ND<	0.005	ND<	0.005	7.71E-03	4.23E-03	135.0%	33.1%	139.0%	ND<	1.7E-05	2.4E-05	41.81%	100.0%
Benz(a)anthracene		ND<	0.007	ND<	0.004	ND<	0.005	5.02E-03	1.57E-03	77.7%	31.4%	83.8%	ND<	1.1E-05	9.2E-06	23.06%	100.0%
Chrysene		ND<	0.009	ND<	0.006	ND<	0.006	6.86E-03	1.61E-03	58.3%	31.0%	66.1%	ND<	1.5E-05	9.9E-06	17.49%	100.0%
Benzo(b)fluoranthene		ND<	0.005	ND<	0.004	ND<	0.003	3.86E-03	9.41E-04	60.6%	31.1%	68.1%	ND<	8.4E-06	5.7E-06	17.77%	100.0%
Benzo(k)fluoranthene		ND<	0.012	ND<	0.004	ND<	0.003	6.17E-03	4.77E-03	192.1%	35.6%	195.4%	ND<	1.3E-05	2.6E-05	58.69%	100.0%
Benzo(a)pyrene		ND<	0.011	ND<	0.003	ND<	0.005	6.40E-03	3.79E-03	147.3%	33.6%	151.1%	ND<	1.4E-05	2.1E-05	43.41%	100.0%
Indeno(1,2,3-cd)pyrene		ND<	0.007	ND<	0.004	ND<	0.004	4.90E-03	2.06E-03	104.6%	32.1%	109.5%	ND<	1.1E-05	1.2E-05	32.31%	100.0%
Dibenzo(a,h)anthracene		ND<	0.005	ND<	0.005	ND<	0.004	4.82E-03	5.61E-04	28.9%	30.7%	42.1%	ND<	1.1E-05	4.4E-06	7.95%	100.0%
Benzo(g,h,i)perylene		ND<	0.003	ND<	0.006	ND<	0.002	ND<	3.96E-03	2.08E-03	130.4%	33.0%	134.5%	ND<	8.7E-06	1.2E-05	39.23%	100.0%
2-Methylnaphthalene			0.071		0.078		0.028	5.90E-02	2.68E-02	112.8%	10.0%	113.3%		1.3E-04	1.5E-04	34.69%	0.0%
7,12-Dimethbenz(a)anth		ND<	0.019	ND<	0.022	ND<	0.023	ND<	2.14E-02	2.09E-03	24.2%	30.6%	39.1%	ND<	4.7E-05	1.8E-05	7.37%	100.0%
3-Methylcholanthrene		ND<	0.004	ND<	0.006	ND<	0.005	ND<	5.12E-03	6.87E-04	33.3%	30.7%	45.3%	ND<	1.1E-05	5.1E-06	10.31%	100.0%
									AVERAGES:	**124.4%**	**29.7%**	**129.7%**		**2.08E-04**	**1.93E-04**	**37.7%**	

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PARAMETER	RUN #1	RUN #2	RUN #3	AVERAGE	STD DEV (Spi)	%STDEV (Spi,%)	N STDEV (Spi')	% BIAS (Bpi,%)	BIAS (Bpi)
PAH STACK:									
F-factor, dscf/mmBtu	8,615	8,619	8,622	8,618	3.39	0.04%	1.96	0.00%	0.00
HHV, Btu/scf @68F	999	998	999	998	0.57	0.06%	0.33	0.00%	0.00
FUEL FLOW, kscfhr@68F	3,069	3,071	3,076	3,072	4	0.12%	2	0.00%	NA
UNIT LOAD, avi MW	326	326	327	326	0.25	0.08%	0.15	0.00%	0.00
HEAT RATE, Btu/MWhr	9.40E+06	9.39E+06	9.40E+06	9.40E+06	8.45E+03	0.09%	4.88E+03	0.00%	0.00E+00
%O2	6.13	6.04	6.43	6.20	0.20	3.29%	0.12	0.00%	0.00
O2 Correction Factor	1.415	1.406	1.444	1.422	0.02	1.40%	0.01	0.00%	0.00
Particle Collection Bias								10%	

DEGREES FREEDOM	T-VALUE
1	12.71
2	4.30
3	3.18
4	2.78
5	2.57
6	2.45
7	2.37
8	2.31

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RPDM FOR MIXED	RPDM ALL ND	CONC. DELTA P DETERMINATION NORM. STD DEV (Spc')	ND BIAS (Bpc1)	> OF NSTD OR BIAS	Particle Coll. Eff. Bias (Bpc2)	THETA CALCULATIONS FOR: CONC. (THETAc)	HEAT RT (THETAhr)	F-factor (THETAff)	RESULTS: Sr	Br	vr	vr	t:	Ur	% Ur
26.29%	26.29%	3.18E-01	0.00E+00	NSTDV	1.59E-01	2.2E-03	3.7E-10	4.0E-07	6.9E-04	3.5E-04	2.00	2	4.3	3.0E-03	86.4%
50.00%	49.90%	2.99E-03	2.99E-03	NSTDV	7.93E-04	2.2E-03	1.8E-12	2.0E-09	6.5E-06	5.9E-06	2.00	2	4.3	2.9E-05	166.1%
50.00%	39.75%	2.05E-03	2.10E-03	**BIAS**	6.62E-04	2.2E-03	1.5E-12	1.7E-09	4.7E-06	4.8E-06	2.00	2	4.3	2.1E-05	143.4%
50.00%	38.97%	4.84E-03	5.13E-03	**BIAS**	1.64E-03	2.2E-03	3.8E-12	4.2E-09	1.1E-05	1.2E-05	2.00	2	4.3	4.7E-05	131.2%
96.14%	77.55%	1.59E-02	2.94E-03	NSTDV	2.20E-03	2.2E-03	5.1E-12	5.6E-09	3.5E-05	8.0E-06	2.00	2	4.3	1.5E-04	311.0%
55.11%	76.89%	1.08E-02	6.92E-03	NSTDV	1.85E-03	2.2E-03	4.3E-12	4.7E-09	2.4E-05	1.6E-05	2.00	2	4.3	1.0E-04	253.1%
50.00%	53.48%	2.64E-03	2.10E-03	NSTDV	6.25E-04	2.2E-03	1.5E-12	1.6E-09	5.8E-06	4.8E-06	2.00	2	4.3	2.5E-05	185.2%
50.00%	41.81%	2.44E-03	2.46E-03	**BIAS**	7.77E-04	2.2E-03	1.8E-12	2.0E-09	5.3E-06	5.6E-06	2.00	2	4.3	2.4E-05	139.0%
50.00%	23.06%	9.06E-04	1.50E-03	**BIAS**	5.02E-04	2.2E-03	1.2E-12	1.3E-09	2.0E-06	3.4E-06	2.00	2	4.3	9.2E-06	83.8%
50.00%	17.49%	9.31E-04	2.02E-03	**BIAS**	6.86E-04	2.2E-03	1.6E-12	1.7E-09	2.0E-06	4.7E-06	2.00	2	4.3	9.9E-06	66.1%
50.00%	17.77%	5.43E-04	1.14E-03	**BIAS**	3.86E-04	2.2E-03	9.0E-13	9.8E-10	1.2E-06	2.6E-06	2.00	2	4.3	5.7E-06	68.1%
50.00%	58.69%	2.76E-03	2.11E-03	NSTDV	6.17E-04	2.2E-03	1.4E-12	1.6E-09	6.0E-06	4.8E-06	2.00	2	4.3	2.6E-05	195.4%
50.00%	43.41%	2.09E-03	2.05E-03	NSTDV	6.40E-04	2.2E-03	1.5E-12	1.6E-09	4.8E-06	4.7E-06	2.00	2	4.3	2.1E-05	151.1%
50.00%	32.31%	1.09E-03	1.50E-03	**BIAS**	4.90E-04	2.2E-03	1.1E-12	1.2E-09	2.6E-06	3.4E-06	2.00	2	4.3	1.2E-05	109.5%
50.00%	7.95%	3.24E-04	1.40E-03	**BIAS**	4.82E-04	2.2E-03	1.1E-12	1.2E-09	7.1E-07	3.2E-06	2.00	2	4.3	4.4E-06	42.1%
50.00%	39.23%	1.20E-03	1.24E-03	**BIAS**	3.96E-04	2.2E-03	9.2E-13	1.0E-09	2.6E-06	2.9E-06	2.00	2	4.3	1.2E-05	134.5%
34.69%	34.69%	1.55E-02	0.00E+00	NSTDV	5.90E-03	2.2E-03	1.4E-11	1.5E-08	3.4E-05	1.3E-05	2.00	2	4.3	1.5E-04	113.3%
50.00%	7.37%	1.21E-03	6.21E-03	**BIAS**	2.14E-03	2.2E-03	5.0E-12	5.4E-09	2.6E-06	1.4E-05	2.00	2	4.3	1.8E-05	39.1%
50.00%	10.31%	3.97E-04	1.49E-03	**BIAS**	5.12E-04	2.2E-03	1.2E-12	1.3E-09	8.7E-07	3.4E-06	2.00	2	4.3	5.1E-06	45.3%
															129.7%

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SPECIES	LOC	RUN #1	RUN #2 In ug/Nm3	RUN #3	AVERAGE (r)	SAMPLE STD. DEV. (Spl)	% SAMPLE RND ERR (Sr,%)	SAMPLE % BIAS (Br,%)	% UNCERT. (Ur,%)	ABSOL. VALUE In lb/hr	ABSOL. UNCERT. (Ur)	% RPDM	% CONTRIB OF ND, TO AVG
total Chlorobiphenyls	OUT	ND< 0.008	ND< 0.004	ND< 0.003	4.78E-03	2.49E-03	129.4%	32.9%	133.5%	ND< 1.0E-05	1.4E-05	39.70%	100.0%
total Dichlorobiphenyls		ND< 0.005	ND< 0.003	ND< 0.001	3.08E-03	1.90E-03	153.1%	33.8%	156.8%	ND< 6.7E-06	1.1E-05	42.26%	100.0%
total Trichlorobiphenyls		ND< 0.078	ND< 0.007	ND< 0.002	2.89E-02	4.26E-02	365.5%	46.2%	368.4%	ND< 6.3E-05	2.3E-04	113.06%	100.0%
total Tetrachlorobiphenyls		ND< 0.002	ND< 0.001	ND< 0.002	1.54E-03	2.38E-04	38.3%	30.8%	49.1%	ND< 3.4E-06	1.7E-06	10.63%	100.0%
total Pentachlorobiphenyls		ND< 0.005	ND< 0.004	ND< 0.004	4.33E-03	9.42E-04	54.1%	31.0%	62.3%	ND< 9.5E-06	5.9E-06	16.07%	100.0%
total Hexachlorobiphenyls		ND< 0.001	ND< 0.001	ND< 0.001	1.19E-03	1.19E-04	24.8%	30.6%	39.4%	ND< 2.6E-06	1.0E-06	7.18%	100.0%
total Heptachlorobiphenyls		ND< 0.002	ND< 0.002	ND< 0.002	1.66E-03	6.99E-05	10.4%	30.6%	32.3%	ND< 3.6E-06	1.2E-06	2.84%	100.0%
total Octachlorobiphenyls		ND< 0.001	ND< 0.001	ND< 0.001	8.88E-04	1.50E-04	41.8%	30.8%	51.9%	ND< 1.9E-06	1.0E-06	11.35%	100.0%
total Nonachlorobiphenyls		ND< 0.001	ND< 0.001	ND< 0.001	1.19E-03	1.75E-04	36.6%	30.7%	47.8%	ND< 2.6E-06	1.2E-06	11.23%	100.0%
Decachlorobiphenyl		ND< 0.004	ND< 0.003	ND< 0.002	3.14E-03	7.70E-04	60.8%	31.1%	68.3%	ND< 6.9E-06	4.7E-06	17.90%	100.0%
TOTAL PCB		ND< 0.078	ND< 0.007	ND< 0.004	2.95E-02	4.21E-02	354.7%	45.4%	357.6%	ND< 6.4E-05	2.3E-04	109.82%	100.0%
						AVERAGES:	91.5%	32.9%	101.0%	1.11E-05	2.74E-05	27.2%	

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PARAMETER	RUN #1	RUN #2	RUN #3	AVERAGE	STD DEV (Spi)	%STDEV (Spi,%)	N STDEV (Spi')	% BIAS (Bpi,%)	BIAS (Bpi)
PCD STACK:									
F-factor, dscf/mmBtu	8,615	8,619	8,622	8,618	3.39	0.04%	1.96	0.00%	0.00
HHV, Btu/scf @68F	999	998	999	998	0.57	0.06%	0.33	0.00%	0.00
FUEL FLOW, kscfhr@68F	3,069	3,071	3,076	3,072	4	0.12%	2	0.00%	NA
UNIT LOAD, net MW	326	326	327	326	0.25	0.08%	0.15	0.00%	0.00
HEAT RATE, Btu/MWhr	9.40E+06	9.39E+06	9.40E+06	9.40E+06	8.45E+03	0.09%	4.88E+03	0.00%	0.00E+00
%O2	6.13	6.04	6.43	6.20	0.20	3.29%	0.12	0.00%	0.00
O2 Correction Factor	1.415	1.406	1.444	1.422	0.02	1.40%	0.01	0.00%	0.00
Particle Collection Bias								10%	

DEGREES FREEDOM	T-VALUE
1	12.71
2	4.30
3	3.18
4	2.78
5	2.57
6	2.45
7	2.37
8	2.31

PCB - AIR
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RPDM FOR MIXED	RPDM ALL ND	CONC. DELTA P DETERMINATION NORM. STD DEV (Spc')	ND BIAS (Bpc1)	> OF NSTD OR BIAS	Particle Coll. Eff. Bias (Bpc2)	THETA CALCULATIONS FOR: CONC. (THETAc)	HEAT RT (THETAhr)	F-factor (THETAff)	RESULTS: Sr	Br	vr	vr	t-	Ur	% Ur
50.00%	39.70%	1.44E-03	1.50E-03	**BIAS**	4.78E-04	2.2E-03	1.1E-12	1.2E-09	3.1E-06	3.4E-06	2.0	2	4.3	1.4E-05	133.5%
50.00%	42.26%	1.09E-03	9.94E-04	NSTDV	3.08E-04	2.2E-03	7.2E-13	7.8E-10	2.4E-06	2.3E-06	2.0	2	4.3	1.1E-05	156.8%
73.19%	113.06%	2.46E-02	1.31E-02	NSTDV	2.89E-03	2.2E-03	6.7E-12	7.3E-09	5.4E-05	2.9E-05	2.0	2	4.3	2.3E-04	368.4%
50.00%	10.63%	1.37E-04	4.49E-04	**BIAS**	1.54E-04	2.2E-03	3.6E-13	3.9E-10	3.0E-07	1.0E-06	2.0	2	4.3	1.7E-06	49.1%
50.00%	16.07%	5.44E-04	1.27E-03	**BIAS**	4.33E-04	2.2E-03	1.0E-12	1.1E-09	1.2E-06	2.9E-06	2.0	2	4.3	5.9E-06	62.3%
50.00%	7.18%	6.85E-05	3.45E-04	**BIAS**	1.19E-04	2.2E-03	2.8E-13	3.0E-10	1.5E-07	8.0E-07	2.0	2	4.3	1.0E-06	39.4%
50.00%	2.84%	4.03E-05	4.81E-04	**BIAS**	1.66E-04	2.2E-03	3.9E-13	4.2E-10	8.8E-08	1.1E-06	2.0	2	4.3	1.2E-06	32.3%
50.00%	11.35%	8.64E-05	2.59E-04	**BIAS**	8.88E-05	2.2E-03	2.1E-13	2.3E-10	1.9E-07	6.0E-07	2.0	2	4.3	1.0E-06	51.9%
50.00%	11.23%	1.01E-04	3.45E-04	**BIAS**	1.19E-04	2.2E-03	2.8E-13	3.0E-10	2.2E-07	8.0E-07	2.0	2	4.3	1.2E-06	47.8%
50.00%	17.90%	4.44E-04	9.25E-04	**BIAS**	3.14E-04	2.2E-03	7.3E-13	8.0E-10	9.7E-07	2.1E-06	2.0	2	4.3	4.7E-06	68.3%
71.57%	109.82%	2.43E-02	1.31E-02	NSTDV	2.95E-03	2.2E-03	6.8E-12	7.5E-09	5.3E-05	2.9E-05	2.0	2	4.3	2.3E-04	357.6%
															124.3%

VOC/FORM – AIR
UNCERTAINTY ANALYSIS
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SPECIES	LOC	RUN #3A	RUN #3B in ppb	RUN #3C	AVERAGE (r)	SAMPLE STD. DEV. (Spl)	% SAMPLE RND ERR (Sr,%)	SAMPLE % BIAS (Br,%)	% UNCERT. (Ur,%)	ABSOL. VALUE in lb/hr	ABSOL. UNCERT. (Ur)	% RPDM	% CONTRIB OF ND, TO AVG
BASELINE													
BENZENE	OUT	0.82	0.44	0.36	5.40E-01	2.46E-01	113.1%	0.0%	113.1%	4.2E-03	4.8E-03	34.57%	0.0%
TOLUENE		4.5	4.3		4.40E+00	9.90E-02	20.2%	0.0%	20.2%	4.1E-02	8.2E-03	3.18%	0.0%
FORMALDEHYDE	OUT	5.2	6.8	5.8	5.95E+00	7.90E-01	33.0%	0.0%	33.0%	1.8E-02	5.9E-03	9.41%	0.0%
MINIMUM LOAD, NORMAL O2													
		RUN #4A	RUN #4B										
BENZENE	OUT	0.29	0.48		3.85E-01	1.34E-01	313.4%	0.0%	313.4%	1.3E-03	4.1E-03	49.35%	0.0%
TOLUENE		0.79	0.92		8.55E-01	9.19E-02	96.6%	0.0%	96.6%	3.4E-03	3.3E-03	15.20%	0.0%
FORMALDEHYDE	OUT	5.4	5.0		5.19E+00	2.69E-01	46.5%	0.0%	46.5%	6.7E-03	3.1E-03	7.32%	0.0%
MINIMUM LOAD, LOW O2													
		RUN #5A	RUN #5B										
BENZENE	OUT	0.22	0.33		2.75E-01	7.78E-02	254.0%	0.0%	254.0%	8.5E-04	2.1E-03	40.00%	0.0%
TOLUENE		0.39	0.77		5.80E-01	2.69E-01	416.0%	0.0%	416.0%	2.1E-03	8.7E-03	65.52%	0.0%
FORMALDEHYDE	OUT	4.7	4.5		4.61E+00	1.16E-01	22.5%	0.0%	22.5%	5.4E-03	1.2E-03	3.55%	0.0%
MINIMUM LOAD, HIGH O2													
		RUN #6A	RUN #6B										
BENZENE	OUT	0.46			4.60E-01	NOTE: NO UNCERTAINTY CALCULATED; ONLY ONE VALID RUN AVAILABLE.							
TOLUENE		0.77			7.70E-01	NOTE: NO UNCERTAINTY CALCULATED; ONLY ONE VALID RUN AVAILABLE.							
FORMALDEHYDE	OUT	4.3	7.8		6.05E+00	2.46E+00	365.3%	0.0%	365.3%	7.9E-03	2.9E-02	57.53%	0.0%

VOC/FORM – AIR
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PARAMETER	RUN #1	RUN #2	RUN #3	AVERAGE	STD DEV (Spi)	%STDEV (Spi,%)	N STDEV (Spi')	% BIAS (Bpi,%)	BIAS (Bpi)
VOC BASELINE:									
F-factor, dscf/mmBtu	8,615	8,619	8,622	8,618	3.39	0.04%	1.96	0.00%	0.00
HHV, Btu/scf @68F	999	998	999	998	0.57	0.06%	0.33	0.00%	0.00
FUEL FLOW, kscfhr@68F	3,076	3,076	3,076	3,076	0	0.00%	0	0.00%	NA
UNIT LOAD, net MW	326	326	327	326	0.25	0.08%	0.15	0.00%	0.00
HEAT RATE, Btu/MWhr	9.42E+06	9.40E+06	9.40E+06	9.41E+06	9.51E+03	0.10%	5.49E+03	0.00%	0.00E+00
%O2	6.63	6.63	6.63	6.63	0.00	0.00%	0.00	0.00%	0.00
O2 Correction Factor	1.465	1.465	1.465	1.465	0.00	0.00%	0.00	0.00%	0.00
Particle Collection Bias								0%	
MIN LOAD, NORM O2:									
F-factor, dscf/mmBtu	8,615	8,619	8,622	8,618	3.39	0.04%	1.96	0.00%	0.00
HHV, Btu/scf @68F	999	998	999	998	0.57	0.06%	0.33	0.00%	0.00
FUEL FLOW, kscfhr@68F	1,237	1,237		1,237	0	0.00%	0	0.00%	NA
UNIT LOAD, net MW	119	119		119	0.00	0.00%	0.00	0.00%	0.00
HEAT RATE, Btu/MWhr	1.04E+07	1.04E+07		1.04E+07	7.26E+03	0.07%	4.19E+03	0.00%	0.00E+00
%O2	7.55	7.55		7.55	0.00	0.00%	0.00	0.00%	0.00
O2 Correction Factor	1.566	1.566		1.566	0.00	0.00%	0.00	0.00%	0.00
Particle Collection Bias								0%	
MIN LOAD, MIN O2:									
F-factor, dscf/mmBtu	8,615	8,619	8,622	8,618	3.39	0.04%	1.96	0.00%	0.00
HHV, Btu/scf @68F	999	998	999	998	0.57	0.06%	0.33	0.00%	0.00
FUEL FLOW, kscfhr@68F	1,235	1,235		1,235	0	0.00%	0	0.00%	NA
UNIT LOAD, net MW	119	119		119	0.00	0.00%	0.00	0.00%	0.00
HEAT RATE, Btu/MWhr	1.04E+07	1.04E+07		1.04E+07	7.25E+03	0.07%	4.18E+03	0.00%	0.00E+00
%O2,	6.25	6.25		6.25	0.00	0.00%	0.00	0.00%	0.00
O2 Correction Factor	1.427	1.427		1.427	0.00	0.00%	0.00	0.00%	0.00
Particle Collection Bias								0%	
MIN LOAD, MAX O2:									
F-factor, dscf/mmBtu	8,615	8,619	8,622	8,618	3.39	0.04%	1.96	0.00%	0.00
HHV, Btu/scf @68F	999	998	999	998	0.57	0.06%	0.33	0.00%	0.00
FUEL FLOW, kscfhr@68F	1,248	1,248		1,248	0	0.00%	0	0.00%	NA
UNIT LOAD, net MW	118	118		118	0.00	0.00%	0.00	0.00%	0.00
HEAT RATE, Btu/MWhr	1.05E+07	1.05E+07		1.05E+07	7.35E+03	0.07%	4.24E+03	0.00%	0.00E+00
%O2	7.50	7.50		7.50	0.00	0.00%	0.00	0.00%	0.00

RPDM FOR MIXED	RPDM ALL ND	CONC. DELTA P DETERMINATION NORM. STD DEV (Spc')	ND BIAS (Bpc1)	> OF NSTD OR BIAS	Particle Coll. Eff. Bias (Bpc2)	THETA CALCULATIONS FOR: CONC. (THETAc)	HEAT RT (THETAhr)	F-factor (THETAff)	RESULTS: Sr	Br	vr	vr	t-	Ur	% Ur
34.57%	34.57%	1.42E-01	0.00E+00	NSTDV	0.00E+00	7.9E-03	4.5E-10	4.9E-07	1.1E-03	0.0E+00	2.00	2	4.3	4.8E-03	113.1%
3.18%	3.18%	7.00E-02	0.00E+00	NSTDV	0.00E+00	9.3E-03	4.3E-09	4.7E-06	6.5E-04	0.0E+00	1.00	1	12.7	8.2E-03	20.2%
9.41%	9.41%	4.56E-01	0.00E+00	NSTDV	0.00E+00	3.0E-03	1.9E-09	2.1E-06	1.4E-03	0.0E+00	2.00	2	4.3	5.9E-03	33.0%
49.35%	49.35%	9.50E-02	0.00E+00	NSTDV	0.00E+00	3.4E-03	1.3E-10	1.5E-07	3.2E-04	0.0E+00	1.00	1	12.7	4.1E-03	313.4%
15.20%	15.20%	6.50E-02	0.00E+00	NSTDV	0.00E+00	4.0E-03	3.3E-10	4.0E-07	2.6E-04	0.0E+00	1.00	1	12.7	3.3E-03	96.6%
7.32%	7.32%	1.90E-01	0.00E+00	NSTDV	0.00E+00	1.3E-03	6.5E-10	7.8E-07	2.5E-04	0.0E+00	1.00	1	12.7	3.1E-03	46.5%
40.00%	40.00%	5.50E-02	0.00E+00	NSTDV	0.00E+00	3.1E-03	8.1E-11	9.8E-08	1.7E-04	0.0E+00	1.00	1	12.7	2.1E-03	254.0%
65.52%	65.52%	1.90E-01	0.00E+00	NSTDV	0.00E+00	3.6E-03	2.0E-10	2.4E-07	6.9E-04	0.0E+00	1.00	1	12.7	8.7E-03	416.0%
3.55%	3.55%	8.18E-02	0.00E+00	NSTDV	0.00E+00	1.2E-03	5.2E-10	6.3E-07	9.7E-05	0.0E+00	1.00	1	12.7	1.2E-03	22.5%

NOTE: NO UNCERTAINTY CALCULATED FOR RUN 6 BENZENE AND TOLUENE; ONLY ONE VALID RUN AVAILABLE.

NOTE: NO UNCERTAINTY CALCULATED FOR RUN 6 BENZENE AND TOLUENE; ONLY ONE VALID RUN AVAILABLE.

57.53%	57.53%	1.74E+00	0.00E+00	NSTDV	0.00E+00	1.3E-03	7.5E-10	9.2E-07	2.3E-03	0.0E+00	1.00	1	12.7	2.9E-02	365.3%

APPENDIX G
QUALITY ASSURANCE AND QUALITY CONTROL DATA

This appendix presents detailed quality assurance and quality control (QA/QC) data for the flue gas and natural gas samples for Site 121. The QA/QC data includes results of duplicate samples, spiked samples and laboratory check standards (LCS). Additional QA/QC data such as instrument calibration data required by the sampling and analytical methodology is maintained by Carnot and the laboratory. QA/QC data is grouped by sample type and analysis. All data pertaining to an analysis is presented together. Analytical data and blank analyses are presented in Appendix H. QA/QC results are presented in the following tables.

TABLE G-1
SUMMARY OF QUALITY CONTROL RESULTS FOR EXHAUST GAS METALS ANALYSES

Duplicate Sample Results

3-MTLS

Element	Method	Sample Value ug/train	Duplicate Value, ug/train	RPD	Data Quality Objective for Duplicates	Comments
Arsenic**	ICP-HYDRIDE	2.4	4.6	61	90-110	Exceeds Limit
Barium	ICP-AES	48	48	0.7	90-110	
Beryllium	ICP-AES	ND<0.1	ND<0.1	NC	90-110	
Cadmium	ICP-AES	ND<0.3	ND<0.3	NC	90-110	
Chromium	ICP-AES	7.1	7.0	1.2	90-110	
Cobalt	ICP-AES	ND<1	ND<1	NC	90-110	
Copper	ICP-AES	12	11	2.6	90-110	
Lead	GFAA	6	MSA	NC	90-110	
Manganese	ICP-AES	3.7	3.6	2.0	90-110	
Mercury						
FH/BH	CVAAS	ND<3	ND<3	NC	90-110	
KMNO4	CVAAS	0.865	0.0757	13	90-110	Exceeds Limit
Molybdenum	ICP-AES	17	16	2.0	90-110	
Nickel	ICP-AES	8.1	6.3	26	90-110	Exceeds Limit
Selenium**	ICP-HYDRIDE	ND<0.28	ND<0.28	NC	90-110	
Phosphorus	ICP-AES	46	50	8.2	90-110	
Vanadium	ICP-AES	3.9	4.1	5.7	90-110	

Notes:
RPD: Relative Percent Difference
MSA: Samples analyzed by the Method of Standard Additions
NC: Not calculated – there were no detected values
** Arsenic and Selenium ICP-HYDRIDE duplicate data is from a different sample analyzed in the same batch as Site 121 samples.

TABLE G-1 (continued)
SUMMARY OF QUALITY CONTROL RESULTS FOR
EXHAUST GAS METALS ANALYSES

Spike Results

Element	Lab blank Pre-digestion % Recovery	3-MTLS Post-digestion % Recovery	Data Quality Objective for Spikes	Comments
Arsenic**	89	92	75-124	
Barium		86	75-125	
Beryllium		81	75-125	
Cadmium		81	75-125	
Chromium		78	75-125	
Cobalt		75	75-125	
Copper		81	75-125	
Lead		MSA	75-125	
Manganese		79	75-125	
Mercury				
FH/BH	109	106	75-125	
KMNO4	96	95	75-125	
Molybdenum		78	75-125	
Nickel		70	75-125	Post-digestion exceeds limit
Selenium**	78	91	75-125	
Phosphorus		84	75-125	
Vanadium		81	75-125	

Laboratory Check Standards Results

Element	Initial Calibration % Recovery	Continuing Calibration % Recovery	Data Quality Objective for LCS
Arsenic	99.67%	93.42%	90-110
Barium	101.30%	100.30%	90-110
Beryllium	93.52%	91.84%	90-110
Cadmium	102.70%	102.22%	90-110
Chromium	104.10%	101.60%	90-110
Cobalt	101.84%	99.72%	90-110
Copper	102.48%	98.96%	90-110
Lead	MSA	MSA	90-110
Manganese	105.04%	103.32%	90-110
Mercury			
FH/BH	103.75%	102.50%	80-120
KMNO4	98.75%	94.25%	80-120
Molybdenum	98.86%	97.18%	90-110
Nickel	103.12%	101.36%	90-110
Selenium	101.75%	93.00%	90-110
Phosphorus	102.54%	102.24%	90-110
Vanadium	99.28%	98.16%	90-110

Correlation Coefficients for MSA Data, R2

Sample ID	Arsenic, R2	Selenium, R2	Lead, R2	Data Quality Objective for MSA
LAB BLANK	0.9996	0.9949	0.9969	>0.995
1-MTLS	0.9997	0.9672	0.9989	>0.995
2-MTLS	0.9991	0.9999	0.9977	>0.995
3-MTLS	0.9983	0.9867	0.9985	>0.995
FB-MTLS	1.0000	1.0000	0.9992	>0.995

Notes:
MSA: Samples analyzed by the Method of Standard Additions
The MSA data for Arsenic and Selenium was not used due to variable detection limits. ICP-HYDRIDE data was reported instead.
** Arsenic and Selenium ICP-HYDRIDE recovery data is from a different sample analyzed in the same batch as Site 121 samples.

TABLE G-2
SUMMARY OF QUALITY CONTROL RESULTS FOR EXHAUST GAS PAH ANALYSES

Duplicate Matrix Spike Recoveries:	Blank Matrix Spike #1 % Recovery	Blank Matrix Spike #2 % Recovery	RPD	Data Quality Objective for Duplicates	Comments
Naphthalene	106	47	77	<50	Exceeds Limit
Acenaphthylene	121	119	1.7	<50	
Acenaphthene	66	66	0.0	<50	
Fluorene	81	86	6.0	<50	
Phenanthrene	115	110	4.4	<50	
Anthracene	123	128	4.0	<50	
Fluoranthene	115	115	0.0	<50	
Pyrene	105	103	1.9	<50	
Benz(a)anthracene	113	114	0.9	<50	
Chrysene	137	138	0.7	<50	
Benzo(b)fluoranthene	103	113	9.3	<50	
Benzo(k)fluoranthene	133	127	4.6	<50	
Benzo(a)pyrene	99	102	3.0	<50	
Indeno(1,2,3-cd)pyrene	104	97	7.0	<50	
Dibenzo(a,h)anthracene	64	62	3.2	<50	
Benzo(g,h,i)perylene	99	99	0.0	<50	
2-Methylnaphthalene	NS	NS	NS	–	
7,12-Dimethylbenz(a)anthracene	NS	NS	NS	–	
3-Methylcholanthrene	NS	NS	NS	–	

Duplicate Matrix Spike Internal Recoveries:	Blank Matrix Spike #1 % Recovery	Blank Matrix Spike #2 % Recovery	RPD	Data Quality Objective for Duplicates	Comments
Napthalene-2H8	61	65	6.3	<50	
Acethenapthylene-2H8	68	63	7.6	<50	
Acenapthene–2H10	87	83	4.7	<50	
Fluorene-2H10	93	94	1.1	<50	
Phenanthrene-2H10	92	93	1.1	<50	
Anthracene-2H10	90	83	8.1	<50	
Fluoranthene-2H10	95	96	1.0	<50	
Pyrene-2H10	94	95	1.1	<50	
Benz(a)anthracene-2H12	92	82	11	<50	
Chrysene-2H12	91	87	4.5	<50	
Benzo(b)fluoranthene-2H12	95	87	8.8	<50	
Benzo(k)fluoranthene-2H12	92	88	4.4	<50	
Benzo(a)pyrene-2H12	97	84	14	<50	
Indeno(1,2,3-c,d)pyrene-2H12	92	97	5.3	<50	
Dibenzo(a,h)anthracene-2H14	99	101	2.0	<50	
Benzo(g,h,i)perylene-2H12	95	92	3.2	<50	

RPD: Relative Percent Difference
NS: Not Spiked

TABLE G-2 (continued)
SUMMARY OF QUALITY CONTROL RESULTS FOR
EXHAUST GAS PAH ANALYSES

PAH Recovery Results	Method Blank	Average Matrix Spike	Field Blank	1-PAH	2-PAH	3-PAH	Data Quality Objective for Spikes	Comments
Internal Recoveries, % (added pre-extraction)								
Napthalene-2H8	72	63	55	54	63	60	50-150	
Acethenapthylene-2H8	74	66	53	65	82	77	50-150	
Acenapthene--2H10	83	85	75	77	96	95	50-150	
Fluorene-2H10	88	94	88	83	89	92	50-150	
Phenanthrene-2H10	90	93	87	97	94	96	50-150	
Anthracene-2H10	94	87	81	81	91	90	50-150	
Fluoranthene-2H10	95	96	92	98	100	110	50-150	
Pyrene-2H10	93	95	93	96	100	110	50-150	
Benz(a)anthracene-2H12	91	87	97	97	94	98	50-150	
Chrysene-2H12	87	89	82	75	82	85	50-150	
Benzo(b)fluoranthene-2H12	95	91	94	93	95	97	50-150	
Benzo(k)fluoranthene-2H12	86	90	77	82	86	88	50-150	
Benzo(a)pyrene-2H12	100	91	85	42*	95	94	50-150	
Indeno(1,2,3-c,d)pyrene-2H12	110	95	100	94	110	120	50-150	
Dibenzo(a,h)anthracene-2H14	99	100	95	90	100	110	50-150	
Benzo(g,h,i)perylene-2H12	93	94	89	85	98	100	50-150	
Surrogate Recoveries, % (field spikes)								
Benzo(e)pyrene-2H12	NS	NS	91	87	90	93	50-150	
Terphenyl-2H14	NS	NS	102	107	105	115	50-150	

NS: Not Spiked
* Does not meet Data Quality Objective

TABLE G-3
SUMMARY OF QUALITY CONTROL RESULTS FOR EXHAUST GAS PCB ANALYSES

Duplicate Matrix Spike Recoveries:	Blank Matrix Spike #1 ug	Blank Matrix Spike #2 ug	RPD	Data Quality Objective for Duplicates	Comments
total Chlorobiphenyls	1.7	1.9	11	<50	
total Dichlorobiphenyls	0.82	0.86	4.8	<50	
total Trichlorobiphenyls	0.88	0.94	6.6	<50	
total Tetrachlorobiphenyls	0.44	0.6	31	<50	
total Pentachlorobiphenyls	0.62	0.78	23	<50	
total Hexachlorobiphenyls	0.63	0.84	29	<50	
total Heptachlorobiphenyls	0.66	0.82	22	<50	
total Octachlorobiphenyls	0.7	0.72	2.8	<50	
total Nonachlorobiphenyls	0.65	0.69	6.0	<50	
Decachlorobiphenyl	0.87	0.91	4.5	<50	
TOTAL PCB	8.03	9.04	12	<50	

Duplicate Matrix Spike Internal Recoveries:	Blank Matrix Spike #1 % Recovery	Blank Matrix Spike #2 % Recovery	RPD	Data Quality Objective for Duplicates	Comments
4-Chlorobiphenyl-13C6	48	53	9.9	<50	
3,3,5,5,-tetrachlorobiphenyl-13C12	99	81	20	<50	
2,2,3,3,5,5,6,6,-Octachlorobiphenyl-13C12	87	92	5.6	<50	
Decachlorobiphenyl-13C12	90	98	8.5	<50	

RPD: Relative Percent Difference

TABLE G-3 (continued)
SUMMARY OF QUALITY CONTROL RESULTS FOR EXHAUST GAS PCB ANALYSES

PCB Recovery Results	Method Blank	Average Matrix Spike	Field Blank	1-PAH	2-PAH	3-PAH	Data Quality Objective for Spikes	Comments
Internal Recoveries, % (added pre-extraction)								
4-Chlorobiphenyl-13C6	56	51	67	60	46*	52	50-150	
3,3,5,5,-Tetrachlorobiphenyl-13C12	70	90	80	86	74	78	50-150	
2,2,3,3,5,5,6,6,-Octachlorobiphenyl-13C12	86	90	82	78	84	91	50-150	
Decachlorobiphenyl-13C12	93	94	87	71	77	76	50-150	
Surrogate Recoveries, % (field spikes)								
2,2,3,4,5,5,6-Heptachlorobiphenyl-13C12	NS	NS	88	86	88	93	50-150	

NS: Not Spiked
* Does not meet DataQuality Objective

TABLE G-4
SUMMARY OF QUALITY CONTROL RESULTS FOR EXHAUST GAS FORMALDEHYDE ANALYSES

Sample Duplicate Analysis

Sample ID	Sample ug/sample	Duplicate ug/sample	RPD	Data Quality Objective for Duplicates	Comments
3-B-FB-Form #1	0.28	0.58	70	10	Exceeds DQO
4-A Form #1	0.40	0.42	4.9	10	
5-B-Form #2	0.26	0.57	75	10	Exceeds DQO
Trip Spike	6.56	6.52	0.6	10	

Spike Analysis

	Expected Value ug/sample	Measured Value ug/sample	% Recovery	Data Quality Objective for Spikes	Comments
Matrix Spikes:					
3-A-Form #2	6.72	6.47	96	60-140	
4-A-Form #1	6.72	6.54	97	60-140	
6-A-Form #1	6.72	6.49	97	60-140	
Trip Spike:	5.0	6.56	131	60-140	
Field Spike:	5.0	6.99	140	60-140	

RPD: Relative Percent Difference

TABLE G-5
SUMMARY OF QUALITY CONTROL RESULTS FOR EXHAUST GAS VOC ANALYSES

Sample Duplicate Results

Component	Sample ID	Run # 1 ppb, v/v	Run #2 ppb, v/v	RPD	Data Quality Objective for Duplicates	Comments
Benzene	3-B-VOC	0.69	0.94	31	20	Exceeds Limit
	3-C-VOC	0.38	0.34	11	20	
	5-A-VOC	0.24	0.21	13	20	
	5-B-VOC	0.35	0.31	12	20	
Toluene	3-B-VOC	55.0	66.6	19	20	
	3-C-VOC	4.75	3.90	20	20	
	5-A-VOC	0.43	0.35	21	20	Exceeds Limit
	5-B-VOC	0.75	0.79	5.2	20	

Calibration Standard Identification #'s

Benzene	NIST 1811
Toluene	NIST 1811

Matix spikes were not performed on VOC samples.
RPD: Relative Percnt Difference

TABLE G-6
SUMMARY OF QUALITY CONTROL RESULTS FOR ANALYSIS OF NATURAL GAS

Component	Replicate 1 volume %	Replicate 2 volume %	RPD	Data Quality Objective	Comments
Methane (C1)	96.5	96.5	0.00%	90-110	
Ethane (C2)	1.84	1.85	0.54%	90-110	
Propane (C3)	0.157	0.157	0.00%	90-110	
i-Butane (C4)	0.024	0.023	4.26%	90-110	
n-Butane (C4)	0.027	0.027	0.00%	90-110	
i-Pentane (C5)	ND<0.001	ND<0.001	NC	90-110	
n-Pentane (C5)	ND<0.001	ND<0.001	NC	90-110	
C6 Plus	0.023	0.024	4.26%	90-110	
Carbon Dioxide	0.43	0.43	0.00%	90-110	
Nitrogen (N2)	0.94	0.94	0.00%	90-110	
Carbon Monoxide	0.43	0.43	0.00%	90-110	
Helium	0.034	0.034	0.00%	90-110	
Hydrogen	0.002	0.002	0.00%	90-110	
Oxygen/Argon	ND<0.03	ND<0.03	NC	90-110	
Ethene	ND<0.03	ND<0.03	NC	90-110	
Propene	ND<0.002	ND<0.002	NC	90-110	
1-Butene	ND<0.003	ND<0.003	NC	90-110	
Butadiene	ND<0.006	ND<0.006	NC	90-110	
neo-Pentane	ND<0.001	ND<0.001	NC	90-110	
Pentenes	ND<0.001	ND<0.001	NC	90-110	

NC: Not calculated – there were no detected values.
RPD: Relative Percent Difference

TABLE G-7
NATURAL GAS ANALYSIS OF NIST STANDARD REFERENCE MATERIAL

Component	Replicate 1 volume %	Certified NIST Value volume %	% Difference	Data Quality Objective	Comments
Oxygen/Argon	ND<0.003	ND<0.003	NC	90-110%	
Nitrogen	2.632	2.612	0.77%	90-110%	
Carbon Dioxide	1.002	1.009	0.69%	90-110%	
Methane (C1)	90.435	90.494	0.07%	90-110%	
Ethane (C2)	4.056	4.010	1.15%	90-110%	
Propane (C3)	1.009	1.000	0.90%	90-110%	
i-Butane (C4)	0.308	0.311	0.96%	90-110%	
n-Butane (C4)	0.300	0.306	1.96%	90-110%	
i-Pentane (C5)	0.101	0.103	1.94%	90-110%	
n-Pentane (C5)	0.103	0.101	1.98%	90-110%	
C6 Plus	0.055	0.054	1.85%	90-110%	

APPENDIX H
ANALYTICAL AND BLANK CORRECTION DATA

This Appendix contains summary tables of the laboratory analysis results for the exhaust gas. These tables indicate the analytical results obtained for field blanks, reagent blanks and laboratory preparation blanks. Field blanks are a sampling train that is set up and recovered at the test site using the same procedure as an actual sample. In general, field blanks are not used to correct the result but do indicate the level of the analyte present in the sample train introduced by the recovery procedures. Reagent blanks are collected in the field and consist of reagents and filters used for each sample train. Laboratory preparation blanks consist only of the chemicals needed to decompose and analyze the samples. All blanks are carried through the entire analytical procedure. Corrections to the data for reagent or preparation blanks are noted. For a series of tests the blank correction contribution is calculated as:

$$\frac{\sum_{n=1}^{i} \left(\frac{\textit{Amount of blank correction}}{\textit{Original sample value}} \times 100 \right)}{n}$$

For example, the flue gas arsenic result was corrected for the reagent blank of 0.5 μg. Raw data for the test series were 2.1 and 2.6 μg per train. Metals run 2 was invalidated, so it is not included in the calculation. The blank correction contribution is calculated as:

$$\frac{\left(\frac{0.5}{2.1} \times 100\right) + \left(\frac{0.5}{2.6} \times 100\right)}{2}$$

or

$$\frac{(23.8\% + 19.2\%)}{2}$$

or

$$21.5\%$$

Blank corrections in no case bring the sample value below the reporting limit. If the blank correction results in a value lower than the reporting limit, the final result is presented as detected at the reporting limit.

Tables in this appendix include:

H-1 Trace Metals Analytical Results Summary
H-2 PAH Analytical Results Summary
H-3 PCB Analytical Results Summary
H-4 Formaldehyde Analytical Results Summary
H-5 VOC Analytical Results Summary
H-6 Summary of Blank Corrections Made to Analytical Data

TABLE H-1
TRACE METALS ANALYTICAL RESULTS SUMMARY

Sample I.D.	Laboratory Blank	Reagent Blank	Field Blank	1-MTLS	2-MTLS	3-MTLS	Blank Correction Contribution, % (Average)
			ug/train				
Arsenic	1.3	0.5	1.7	2.1	1.9	2.6	60
Barium	15.0	6.4	13.0	71	57	48	26
Beryllium	ND<0.1	ND<0.1	ND<0.1	ND<0.1	ND<0.1	ND<0.1	0
Cadmium	ND<0.3	ND<0.3	ND<0.3	0.7	ND<0.3	ND<0.3	0
Chromium	3.7	1.0	3.1	15	750	7.1	26
Cobalt	ND<1	ND<1.0	ND<1	ND<1	6	ND<1	0
Copper	3.1	4.1	4.5	18	940	12	19
Lead	1.7	0.6	6.0	6.0	13	6	23
Manganese	2.1	ND<0.8	3.9	4.5	88	3.7	35
Mercury							
FH/BH	ND<0.4	ND<0.6	1.1	ND<2	ND<3	ND<3	0
KMnO4	ND<0.04	ND<0.3	ND<0.5	ND<0.8	0.9	ND<0.7	0
Molybdenum	1.1	ND<0.8	17	18	23	17	6
Nickel	3.0	ND<2	3.0	14	410	8	20
Selenium	ND<0.25	ND<0.25	ND<0.28	ND<0.28	ND<0.28	ND<0.28	0
Phosphorus	22	ND<6	43	39	44	46	51
Vanadium	ND<0.6	ND<0.6	1.8	4.7	7.2	3.9	0

Notes:

Test run 2-MTLS was not used to calculate results due to possible field contamination.

The laboratory method blank was subtracted from the laboratory results to obtain the final results for As, Ba, Cr, Pb,Mn, Mo, Ni, and P.

The reagent blank was subtracted from the laboratory results to obtain the final results for Cu.

Arsenic and Selenium were analyzed by ICP-AES with Hydride generation.

TABLE H-2
PAH ANALYTICAL RESULTS SUMMARY

Sample I.D.	Method Blank	Field Blank	1-PAH	2-PAH	3-PAH
Species					
Naphthalene	2.9	12	6.9	12.0	7.7
Acenaphthylene	ND <0.0080	ND <0.021	ND <0.080	ND <0.023	ND <0.032
Acenaphthene	ND <0.028	ND <0.034	ND<0.061	ND<0.033	ND <0.018
Fluorene	ND <0.030	ND<0.039	ND<0.15	ND<0.069	ND <0.059
Phenanthrene	ND <0.021	ND<0.039	0.310	ND<0.079	ND <0.056
Anthracene	ND <0.019	ND <0.024	ND<0.23	ND <0.055	ND <0.031
Fluoranthene	ND <0.016	ND<0.028	ND<0.065	ND <0.028	ND <0.013
Pyrene	ND <0.015	ND<0.028	ND<0.073	ND <0.028	ND<0.031
Benz(a)anthracene	ND <0.027	ND <0.025	ND <0.039	ND <0.020	ND <0.026
Chrysene	ND <0.020	ND <0.035	ND <0.050	ND <0.030	ND <0.036
Benzo(b)fluoranthene	ND <0.018	ND <0.021	ND <0.027	ND <0.022	ND<0.016
Benzo(k)fluoranthene	ND <0.021	ND <0.028	ND <0.067	ND <0.023	ND <0.015
Benzo(a)pyrene	ND <0.030	ND <0.029	ND <0.061	ND <0.017	ND<0.031
Indeno(1,2,3-cd)pyrene	ND <0.054	ND <0.030	ND <0.042	ND <0.021	ND <0.020
Dibenzo(a,h)anthracene	ND <0.028	ND <0.022	ND <0.028	ND <0.029	ND <0.024
Benzo(g,h,i)perylene	ND <0.032	ND <0.024	ND <0.019	ND <0.034	ND <0.013
2-Methylnaphthalene	ND <0.020	0.061	0.410	0.420	0.16
7,12-Dimethylbenz(a)anthracene	ND <0.13	ND <0.11	ND <0.11	ND <0.12	ND <0.13
3-Methylcholanthrene	ND <0.025	ND <0.032	ND <0.025	ND <0.030	ND <0.031

The PAH results are already corrected by the lab for the laboratory method blank and internal spike recoveries.

TABLE H-3
PCB ANALYTICAL RESULTS SUMMARY

Sample I.D.	Method Blank	Field Blank	1-PAH	2-PAH	3-PAH
Species					
total Chlorobiphenyls	ND<0.017	ND <0.017	ND <0.044	ND <0.020	ND <0.017
total Dichlorobiphenyls	ND <0.012	ND <0.0080	ND <0.029	ND <0.016	ND <0.0070
total Trichlorobiphenyls	ND <0.014	ND <0.0070	ND <0.45	ND <0.037	ND <0.011
total Tetrachlorobiphenyls	ND <0.0090	ND <0.0090	ND <0.0090	ND <0.0070	ND <0.010
total Pentachlorobiphenyls	ND <0.011	ND <0.037	ND <0.031	ND <0.022	ND <0.020
total Hexachlorobiphenyls	ND <0.0090	ND <0.0060	ND <0.0070	ND <0.0070	ND <0.0060
total Heptachlorobiphenyls	ND <0.0090	ND <0.0070	ND <0.010	ND <0.0090	ND <0.0090
total Octachlorobiphenyls	ND <0.0060	ND <0.0060	ND <0.0060	ND <0.0040	ND <0.0050
total Nonachlorobiphenyls	ND <0.0070	ND <0.0070	ND <0.0080	ND <0.0060	ND <0.0060
Decachlorobiphenyl	ND <0.019	ND <0.015	ND <0.023	ND <0.016	ND <0.014
TOTAL PCB	ND <0.019	ND <0.037	ND <0.45	ND <0.037	ND <0.020

The PCB results are corected for internal recoveries.

TABLE H-4
FORMALDEHYDE ANALYTICAL RESULTS SUMMARY

Sample I.D.	ug/Test	Reagent Blank, ug	Blank Correction Contribution	Field Blank
3A-FORM	0.84	0.18	0.0%	0.50
3B-FORM	1.10	0.18	0.0%	0.56
3C-FORM	0.93	0.18	0.0%	1.54
4A-FORM	0.83	0.18	0.0%	
4B-FORM	0.76	0.18	0.0%	0.32
5A-FORM	0.71	0.18	0.0%	
5B-FORM	0.70	0.18	0.0%	0.37
6A-FORM	0.66	0.18	0.0%	
6B-FORM	1.23	0.18	0.0%	1.47
		Average:	0.0%	

TABLE H-5
VOC ANALYTICAL RESULTS SUMMARY

Component	Sample I.D.	ppb, v/v	Pre-test Tedlar Bag Blank	Blank Correction Contribution
Benzene	3A-VOC	0.82	ND<0.1	0.0%
	3B-VOC	0.44	ND<0.1	0.0%
	3C-VOC	0.36	ND<0.1	0.0%
	4A-VOC	0.29	ND<0.1	0.0%
	4B-VOC	0.48	ND<0.1	0.0%
	5A-VOC	0.22	ND<0.1	0.0%
	5B-VOC	0.33	ND<0.1	0.0%
	6A-VOC	0.46	ND<0.1	0.0%
	6B-VOC	•	ND<0.1	0.0%
Toluene	3A-VOC	60.8	0.37	0.0%
	3B-VOC	4.47	0.37	0.0%
	3C-VOC	4.33	0.37	0.0%
	4A-VOC	0.79	0.37	0.0%
	4B-VOC	0.92	0.37	0.0%
	5A-VOC	0.39	0.37	0.0%
	5B-VOC	0.77	0.37	0.0%
	6A-VOC	0.77	0.37	0.0%
	6B-VOC	•	0.37	0.0%

VOC results are not corrected for the tedlar bag blank. The bag was filled with the GC carrier gas (nitrogen) then analyzed. The analysis was performed prior to the test period, therefore the blank levels are not truly representative of field conditons.

• The tedlar bag containing sample 6B-VOC arrived at the lab empty, and was not analyzed.

TABLE H-6
SUMMARY OF BLANK CORRECTIONS MADE TO ANALYTICAL DATA

Sample Type	Parameter	Type of Blank Correction	Blank Correction Contribution
Exhaust Gas	Arsenic	Laboratory Blank	60%
	Barium	Laboratory Blank	26%
	Beryllium	None	0.0%
	Cadmium	None	0.0%
	Chromium	Laboratory Blank	26%
	Cobalt	None	0.0%
	Copper	Reagent Blank	19%
	Lead	Laboratory Blank	23%
	Manganese	Laboratory Blank	35%
	Mercury	None	0.0%
	Molybdenum	Laboratory Blank	6.0%
	Nickel	Laboratory Blank	20%
	Selenium	None	0.0%
	Phosphorus	Laboratory Blank	51%
	Vanadium	None	0.0%
	PAH (all compounds)	None	0.0%
	PCB (all compounds)	None	0.0%
	Formaldehyde	None	0.0%
	Volatile Organic Compounds	None	0.0%