

**Shell Puget Sound Refining Company
Sulfur Recovery Unit #4
Source Test Report for Carbon Monoxide,
Methane, Ethane and Total Hydrocarbons**

**Information Collection Request for
Petroleum Refineries**

ETI Report Number: 11-2084
July 27, 2011

Prepared for:

**Shell Puget Sound Refinery
PO Box 622
Anacortes, WA 98221-0622**

Prepared by:

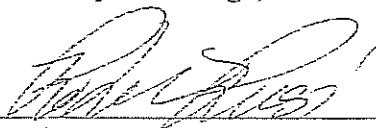
**Emission Technologies, Inc.
15609-D Peterson Rd.
Burlington, WA 98233**

Report Certification

The emission testing for this report was carried out under my direction and supervision. In addition, I have reviewed all analysis and test results, and certify that the test and report meet EPA requirements and that, to the best of my knowledge, this test report is authentic and accurate.

Date: 9-18-11

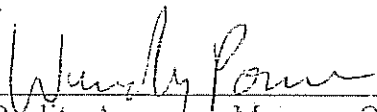
Signed: _____


Operations Manager, QSTI
Robert Rusi

I have reviewed all analysis and test results, and certify that, to the best of my knowledge, this test report is authentic and accurate.

Date: 9-13-11

Signed: _____


Quality Assurance Manager, QSTI
Wendy Pounds



1600 South Second Street
Mount Vernon, WA 98273-5202
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Emission Test Summary:

Please fill out the pertinent information and submit the form with your test plan **and** with the final test report! Submit separate sheets for each emission unit.

Source Name:	Shell Puget Sound Refinery
Test performed by:	Emission Technologies, Inc.
Emission/Process Unit:	SRU4
List Operational Parameters recorded during testing (e.g., Btu input, gallons loaded, steam production, % capacity, fuel feed rate, control device parameters, etc.):	
Regulation requiring test: -----	EPA Letter 114 -----
Required frequency of test:	
Proposed Test Date(s): -----	-----
Actual Test Date(s)	July 27, 2011
Test Method(s): -----	US EPA Methods – 1, 2, 3A, 4, 10, 25A -----
Modifications (if any):	
Pollutant(s), units: -----	O ₂ , CO ₂ , CO, CH ₄ , C ₂ H ₆ , THC -----
Emission or concentration limit:	
Average Emission/Concentration: (include averaging time, correction if applicable)	
In Compliance (Y/N)	
Comments:	
For Official Use Only:	

INVOLVED PARTIES:

Shell Puget Sound Refinery

Contact:

Mike Dubois
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Anacortes, WA 98221-0622

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EPA

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U.S. EPA
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Emission Technologies, Inc.

Contact:

Robert Rusi, QSTI
Wendy Pounds, QSTI
15609-D Peterson Rd.
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Phone: (360) 757-1210

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E-mail: eti@stacktester.com

Report Text

Summary

***ETI Field Data -
Gases***

***ETI Field Data –
Flows & Moisture***

***Quality Assurance
Quality Control***

Report Text

Introduction

Test Overview

Overview of Sampling Methods

Results and Reporting Conditions

As Found

Process Overview

Participants

Introduction:

The Clean Air Act Section 114 letter (dated 03/31/11, OMB Control No. 2060-0657) requesting information/testing (ICR) to promulgate a new Refinery MACT was sent to Shell Puget Sound Refining Company (PSR). The ICR required emissions performance tests at the Sulfur Recovery Unit #4 (SRU4) at the Anacortes, Washington refinery. This report covers the required testing for carbon monoxide (CO), methane (CH₄), ethane (C₂H₆) and total hydrocarbons (THC).

Test Overview:

ETI performed emission testing from the SRU4 stack July 27, 2011. Table 1.0 presents the detailed test plan protocol used. Environmental Protection Agency (EPA) Environmental Protection Agency (EPA) Methods referenced are documented in Title 40 of the Code of Federal Regulations, Part 60, (40 CFR 60) Appendix A.

Table 1.0
Carbon Monoxide and Hydrocarbons

Parameter	Test Method	No. of Runs	Time per Run
Site selection	EPA Method 1	Once per stack	As needed
Stack Gas Flow	EPA Method 2	3 runs	60 minutes
O ₂ /CO ₂	EPA Method 3A	3 runs	60 minutes
Moisture	EPA Method 4	3 runs	60 minutes
CO	EPA Method 10	3 runs	60 minutes
THC	EPA Method 25A	3 runs	60 minutes
CH ₄ , C ₂ H ₆	EPA Method 320	3 runs	60 minutes

Overview of Sampling Methods

EPA Method 1 - Sample and Velocity Traverses for Stationary Sources

EPA Method 1 was used to aid in the representative measurement of pollutant emissions and/or total volumetric flow rate from a stationary source. A measurement site where the effluent stream was flowing in a known direction was selected, and the cross-section of the stack was divided into a number of equal areas. A traverse point was then located within each of these equal areas. The sampling traverse points for Method 1 need only be determined once.

EPA Method 2 - Determination of Stack Gas Velocity and Volumetric Flow Rate

This method is applicable for the determination of the average velocity and volumetric flow rate of a gas stream. The average gas velocity in a stack was determined from the gas density and from the measurement of the average velocity head with a Type S (Staustscheibe or reverse type) pitot tube.

EPA Method 4 - Moisture Content in Stack Gas

This method is applicable for the determination of the moisture content of stack gas. A sample of the gas stream was extracted at a constant rate and then condensed and metered using an EPA Method 5 sample train. The weight gain of moisture condensed was determined gravimetrically by measuring the weight change of the impingers.

EPA Method 3A & 10 – Determination of O₂, CO₂ and CO Gas Concentrations

The testing methodology for target gas concentrations in the flue gas consisted of a continuously operated gas analyzer system. Sample gases were first extracted from the stack through a heated probe/glass fiber filter assembly. A calibration gas purge valve was fitted ahead of the filter assembly for introducing calibration gases to the analyzer system. The samples were transported through Teflon sample lines to a portable unit containing the analyzers. Each of the samples was conditioned while a constant sample extraction rate was maintained. The analyzers detected the concentration of analyte gas within the sample and produced an electrical output signal proportional to analyte gas concentration. The electrical signal was recorded on a digital data acquisition system.

Instrument calibrations (zero and span checks) were performed per Method 7E. Sampling system calibrations and linearity determinations were accomplished by sending EPA Protocol 1 calibration gases to a location ahead of the filter assembly.

All components of the gas sampling and calibration system were constructed of Teflon, 316 stainless steel, or glass. The sample vacuum/pressure pump head was constructed of 316 stainless steel, Viton O-rings, and a Teflon coated diaphragm.

EPA Method 25A – Determination of THC Gas Concentrations

This method is applicable for the determination of total gaseous organic concentration of vapors consisting primarily of alkanes, alkenes and/or arenes (aromatic hydrocarbons). THC concentrations are expressed in terms of propane. The CR exhaust gas was continuously withdrawn at a known sampling rate through a heated filter assembly and a heated Teflon sampling line to a tee attached to the analyzers. One side of this tee went to the flame ionization analyzer (FIA) for THC analysis and the other side went to a moisture knock out. The analyzer detected the concentration of analyte gas from the sample stream and produced an output electrical signal proportional to analyte gas concentration. The electrical signal was recorded on a digital data acquisition system (DAS). A calibration error test was performed immediately prior to the test. Calibration drift tests were performed following each run by sending zero and mid-level calibration gases to the measurement system at the calibration valve assembly. Results are reported as volume concentration equivalents of the calibration gas (propane).

EPA Method 320 – Measurement of Vapor Phase Organic and Inorganic Emissions by Extractive Fourier Transform (FTIR) Spectroscopy

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

Infrared absorption spectroscopy is performed by directing an infrared beam through a sample to a detector. The frequency-dependent infrared absorbance of the sample is measured by comparing this detector signal (single beam spectrum) to a signal obtained without a sample in the beam path (background). Most molecules absorb infrared radiation and the absorbance occurs in a characteristic and reproducible pattern. The infrared spectrum measures fundamental molecular properties and a compound can be identified from its infrared spectrum alone. Within constraints, there is a linear relationship between infrared absorption and compound concentration. If this frequency dependent relationship (absorptivity) is known (measured), it can be used to determine compound concentration in a sample mixture. Absorptivity is measured in the laboratory by preparing standard samples of compounds at known concentrations and measuring the FTIR “reference spectra” of these standard samples. These ‘reference spectra’ are then used in sample analysis: (1) compounds are detected by matching sample absorbance bands with bands in reference spectra, and (2) concentrations are measured by comparing sample band intensities with reference band intensities.

Flue gas was extracted through a heated gas transport and handling system similar to that used for single-component continuous emission monitoring system (CEMS) measurements. The components measured using this method were methane and ethane.

QA/QC

The overall objective of the quality assurance procedures is to representatively sample and accurately analyze components in the gas streams and hence obtain valid measurement of emission concentrations.

Equipment Calibration and Check-out

Sampling and measurement equipment was checked for condition, current calibration, leaks and integrity of systems operation. Connection of the components of the sampling trains and measurement systems were made to verify that they are functioning properly. Calibrations of the components of the sampling equipment and measurement systems were performed according to the procedures published by the United States Environmental Protection Agency (EPA), Document No. EPA-600/4-77-027b in the Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III, Stationary Source Specific Methods.

The reference monitors or emission measurement analyzers were checked for zero drift by injecting several calibration gases. A calibration error check of each analyzer was done prior to testing by sending low-, mid- and high-level calibration gases directly to the analyzers (internal calibration). The analyzers must read within $\pm 2.0\%$ of the calibration span of each analyzer. The high level calibration gas sets the calibration span. External calibrations are made before and after every run. Less than a $\pm 3\%$ drift of the span value(s) (alternatively ≤ 0.5 ppmv absolute difference) is acceptable or the run must be repeated (after performing another calibration error check). The calibration gas was injected into the analyzer at the same flow rate as the sample gas. The calibration gas is injected at the probe in front of the filter to assure continuity of the sample system. A system bias calibration using low-level and one upscale calibration gas was performed at the end of the test. The difference between pre- and post-test system bias must be within $\pm 5\%$ of the calibration span (alternatively ≤ 0.5 ppmv absolute difference) for the test to be valid.

The data acquisition system (DAS) inputs were matched to the output voltages of the analyzers.

Pre-Sample Field Preparation

Sampling and measurement equipment were prepared with reagents and leak checked at representative vacuums to within an acceptable leak rate.

On-site Set-up

Data sheets and the on stack calculator were prepared with preliminary stack measurements. The sampling equipment was placed at the sampling site.

Site Preliminary Measurements

The inside dimensions of the stack, the sample port length, unobstructed distances ahead and behind the sample ports, % moisture, gas composition for molecular weight estimates, stack gas temperature and the sample box support structure were determined in preparation for collection of the first sample. The sample time was selected to generate a sample of at least 40 cubic feet and to collect over 10 milligrams of particulate during each test run. Minimum sample times (usually 60 minutes) were verified from the Test Plan. The preliminary measurements were utilized to perform the calculations of the linear relationship between the “delta H” to operate the sampling train and from the “delta P” reading from the velocity in the exhaust stack.

Sample Collection and Measurements

An on-stack Hewlett-Packard calculator as well as a hand written data sheet are utilized to record all field measurements. The moisture (i.e. EPA Method 4) and other gas analyses performed by the sampling equipment are used as information to set-up and operate the measurement equipment.

Clean-up and Analysis

Detailed clean up and analysis procedures are documented in the Test Plan and in the final report of findings. Dry gas meters were spot checked before and after each series of field tests for their accuracy using critical orifices. Adjustment in the sample gas volume is made based upon the “Y” factor for the dry gas meter.

Report of Findings

A summary table of QA/QC results including duplicate analyses, matrix spikes, field and lab blanks, blank corrections and surrogate and internal standard recoveries are included in the report. A process data summary, provided by the client, is included in the report as well. Data were reported using the EPA Electronic Reporting Tool (ERT) Version 4.

Results and Reporting Conditions

The results of the pollutant emission tests are presented in Section 2. The units of reporting for the gases are parts per million (ppmdv) and pounds per hour (lb/hr). The emission rates presented in the summaries are referenced to EPA standard conditions of 29.92 inches of mercury (“Hg) and 68° F.

As Found:

There were no anomalies for this test.

Process Overview:

Shell PSR SRU #4

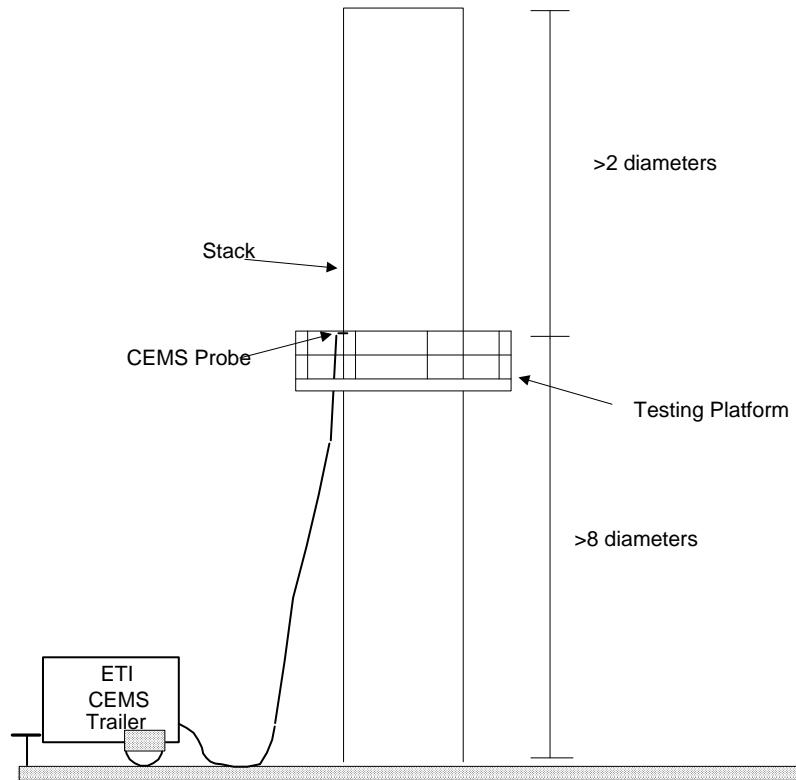


Figure 1 shows a conceptual diagram of the sampling location on the SRU4.

Participants:

- Rob Rusi, Project Manager
- Mr. Dave Worgum, Field Technician
- Mr. Dave Wagner, Field Technician
- Mr. Adam Manning, Field Technician
- Ms. Wendy Pounds, Quality Assurance Supervisor

Mr. Mike Dubois served as project manager for PSR.

Summary

Table 2.0 Gases Summary

Gas Summaries

Client: Shell, PSR
City: Anacortes, WA
Site: SRU4

Date: 07/27/11

ETI Job No: 11-2084

Table 2.0

O₂	Run Number						Average
	1		2		3		
%	3.66		3.58		3.59		3.61
CO₂	Run Number:						Average
	1		2		3		
%	8.48		8.39		8.40		8.42
CO	Run Number:						Average
	1		2		3		
ppmdv	113.83	ADL	111.69	ADL	107.55	ADL	111.02
lb/hr	3.72	ADL	3.65	ADL	3.51	ADL	3.63
Methane	Run Number:						Average
	1		2		3		
ppmwv	0.040		0.027		0.022		0.029
ppmdv	0.044	ADL	0.030	ADL	0.025	ADL	0.033
lb/hr	0.001	ADL	0.00055	ADL	0.00046	ADL	0.00061
Ethane	Run Number:						Average
	1		2		3		
ppmwv	0.117		0.152		0.154		0.141
ppmdv	0.131	ADL	0.169	ADL	0.172	ADL	0.157
lb/hr	0.005	ADL	0.0059	ADL	0.0060	ADL	0.0055
THC	Run Number:						Average
	1		2		3		
ppmwv	0.253		0.263		0.029		0.182
ppmdv	0.283	ADL	0.293	ADL	0.032	DLL	0.203
lb/hr	0.015	ADL	0.015	ADL	0.002	DLL	0.010

Field Data

Table 3.0.0 Traverse Sheet

Table 3.0.1 Calibration Data Sheet

Table 3.0.2 O₂ Analyzer System Bias & Calibration Data

Table 3.0.3 CO₂ Analyzer System Bias & Calibration Data

Table 3.0.5 CO Analyzer System Bias & Calibration Data

Table 3.0.6 THC Analyzer System Bias & Calibration Data

Table 3.1.1 Run 1 Gases

Table 3.1.2 Run 2 Gases

Table 3.1.3 Run 3 Gases

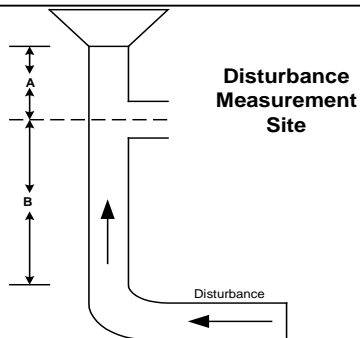
Client: Shell, PSR
City: Anacortes, WA
Site: SRU4

Date: 07/27/11

ETI Job No: 11-2084

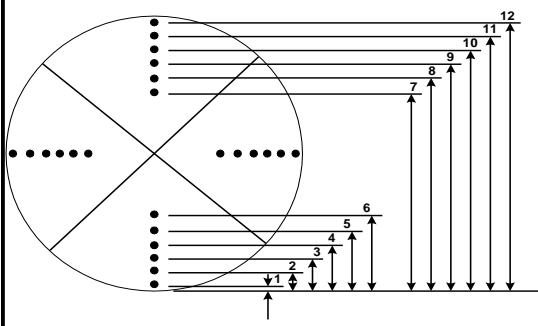
Table 3.0.0
Sample Site Selection and Location of Traverse Points in Circular Stacks
and Determination of Stratification

Traverse Point	% of Diameter Distance	Actual Distance	O ₂ or CO ₂ Conc. (%)	O ₂ or CO ₂ Conc. % diff. of mean	SO ₂ Conc. ppm dv	SO ₂ Conc. % diff. of mean	NO _x Conc. ppm dv	NO _x Conc. % diff. of mean	CO Conc. ppm dv	CO Conc. % diff. of mean
1	16.7	51.7	3.51	-0.4%	-	-	-	-	0.2	-1.8%
2	50.0	83.0	3.53	0.2%	-	-	-	-	0.3	6.5%
3	83.3	114.3	3.53	0.2%	-	-	-	-	0.2	-4.6%
4	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-
Mean:			3.52		-		-		0.3	



Stack Diameter (inches): 94
Port Length (inches): 36
of Traverse Pts. (3,12): 3

3 point sample: $\leq 10\%$ or ± 1 ppm of mean
1 point sample: $\leq 5\%$ or ± 0.5 ppm of mean



Calibration Data

Client: Shell, PSR	ETI: Rob Rusi
Location: Anacortes, WA	Scott Chessnut
Site: SRU4	
Date: 07/27/11	ETI Job No: 11-2084

Table 3.0.1

Instrument Information:

Instrument	Channel	Color	Make	Model	Serial No.
O ₂	-	-	Horiba	MPA-510	41522310072
CO ₂	-	-	Horiba	VIA-510	41522310053
SO ₂	-	-	Bovar	ATM-721	95721M
NO _x	-	-	CAI	300	Y-6007
CO	-	-	Teco	48I	622117815
HCS	-	-	CAI	300	15608014
Recorders	-	-	ETI	P-Series	3

Calibration Information:

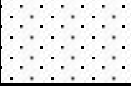
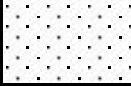
Instrument	Units	Zero	Span	Range	Gas Cyl. No.	Gas Flow (L/min)
O ₂	%	-	12.6	21.9	CC184281	0.5
O ₂	%	-	21.9	21.9	CC79739	0.5
CO ₂	%	-	12.3	21.1	CC184281	0.5
CO ₂	%	-	21.1	21.1	CC79739	0.5
SO ₂	ppmdv	-	196.0	495	EB0021758	0.5
SO ₂	ppmdv	-	495.0	495	CC251960	0.5
NO _x	ppmdv	-	196.0	486	EB0021758	0.5
NO _x	ppmdv	-	486.0	486	CC251960	0.5
CO	ppmdv	-	191.0	479	EB0021758	0.5
CO	ppmdv	-	479.0	479	CC251960	0.5
HCS	ppmv	-	29.5	100	CC251985	0.5
HCS	ppmv	-	50.1	100	CC159061	0.5
HCS	ppmv	-	88.3	100	CC159139	0.5

Client: Shell, PSR
City: Anacortes, WA
Site: SRU4

Date: 07/27/11

ETI Job No: 11-2084

Table 3.0.2
O₂ Analyzer Calibration Data

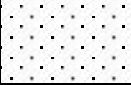
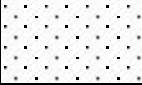
3-Point Linearity Check (Internal Cal)	Direct Calibration Mode						
	Cylinder Value (ppmdv)	Calibration Response (ppmdv)	Difference from Cylinder Value	Difference (% of Calibration Span)			
	Zero Gas	0.00	0.00	0.00	0.00%		
	Mid-Range Gas	12.60	12.65	0.05	0.23%		
	High-Range Gas	21.90	21.90	0.00	0.00%		
40 CFR 60 Method 3A-13.0 Analyzer calibration error ≤2.0% of calibration span or 0.5% absolute difference System Bias must be ≤5.0% of calibration span or 0.5% absolute difference Calibration Drift must be ≤3.0% of calibration span or 0.5% absolute difference Calibration Span = High-Range Gas Cylinder Value Upscale Gas = Mid 12.60							
System Bias and Calibration Drift Assessments	Run	Analyzer Calibration Response (ppmdv) Direct System		Direct - System Difference	Pre - Post System Response	System Bias	Calibration Drift
Zero Gas	Pre	0.00	0.00	0.00		0.00%	
Upscale Gas		12.65	12.38	0.27		1.23%	
Zero Gas	1	0.00	0.02	0.02	0.02	0.09%	0.09%
Upscale Gas		12.65	12.28	0.37	0.10	1.69%	0.46%
Zero Gas	2	0.00	0.02	0.02	0.00	0.09%	0.00%
Upscale Gas		12.65	12.28	0.37	0.00	1.69%	0.00%
Zero Gas	3	0.00	0.04	0.04	0.02	0.18%	0.09%
Upscale Gas		12.65	12.18	0.47	0.10	2.15%	0.46%

Client: Shell, PSR
City: Anacortes, WA
Site: SRU4

Date: 07/27/11

ETI Job No: 11-2084

Table 3.0.3
CO₂ Analyzer Calibration Data


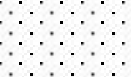
3-Point Linearity Check (Internal Cal)	Direct Calibration Mode						
	Cylinder Value (ppmdv)	Calibration Response (ppmdv)	Difference from Cylinder Value	Difference (% of Calibration Span)			
Zero Gas	0.00	0.00	0.00	0.0%			
Mid-Range Gas	12.30	12.70	0.40	1.9%			
High-Range Gas	21.10	21.07	0.03	0.1%			
40 CFR 60 Method 3A-13.0 Analyzer calibration error ≤2.0% of calibration span or 0.5% absolute difference System Bias must be ≤5.0% of calibration span or 0.5% absolute difference Calibration Drift must be ≤3.0% of calibration span or 0.5% absolute difference Calibration Span = High-Range Gas Cylinder Value Upscale Gas = Mid 12.30							
System Bias and Calibration Drift Assessments	Run	Analyzer Calibration Response (ppmdv) Direct System		Direct - System Difference	Pre - Post System Response	System Bias	Calibration Drift
Zero Gas	Pre	0.00	0.06	0.06		0.3%	
Upscale Gas		12.70	12.68	0.02		0.1%	
Zero Gas	1	0.00	0.04	0.04	0.02	0.2%	0.1%
Upscale Gas		12.70	12.78	0.08	0.10	0.4%	0.5%
Zero Gas	2	0.00	0.04	0.04	0.00	0.2%	0.0%
Upscale Gas		12.70	12.78	0.08	0.00	0.4%	0.0%
Zero Gas	3	0.00	0.03	0.03	0.01	0.1%	0.0%
Upscale Gas		12.70	12.67	0.03	0.11	0.1%	0.5%

Client: Shell, PSR
City: Anacortes, WA
Site: SRU4

Date: 07/27/11

ETI Job No: 11-2084

Table 3.0.4
CO Analyzer Calibration Data

3-Point Linearity Check (Internal Cal)	Direct Calibration Mode						
	Cylinder Value (ppmdv)	Calibration Response (ppmdv)	Difference from Cylinder Value	Difference (% of Calibration Span)			
Zero Gas	0.0	0.16	0.16	0.03%			
Mid-Range Gas	191.0	185.0	6.00	1.25%			
High-Range Gas	479.0	488.0	9.00	1.88%			
40 CFR 60 Method 10-13.0 Analyzer calibration error ≤2.0% of calibration span or 0.5 ppmv absolute difference System Bias must be ≤5.0% of calibration span or 0.5 ppmv absolute difference Calibration Drift must be ≤3.0% of calibration span or 0.5 ppmv absolute difference Calibration Span = High-Range Gas Cylinder Value Upscale Gas = High 479.0							
System Bias and Calibration Drift Assessments	Run	Analyzer Calibration Response (ppmdv) Direct System		Direct - System Difference	Pre - Post System Response	System Bias	Calibration Drift
Zero Gas	Pre	0.16	0.80	0.64		0.13%	
Upscale Gas		488.0	488.0	0.00		0.00%	
Zero Gas	1	0.16	0.20	0.04	0.60	0.01%	0.13%
Upscale Gas		488.0	492.0	4.00	4.00	0.84%	0.84%
Zero Gas	2	0.16	0.20	0.04	0.00	0.01%	0.00%
Upscale Gas		488.0	492.0	4.00	0.00	0.84%	0.00%
Zero Gas	3	0.16	0.30	0.14	0.10	0.03%	0.02%
Upscale Gas		488.0	489.0	1.00	3.00	0.21%	0.63%

Client: Shell, PSR
City: Anacortes, WA
Site: SRU4

Date: 07/27/11

ETI Job No: 11-2084

Table 3.0.5
HC Analyzer Calibration Data

3-Point Linearity Check (Internal Cal)	Direct Calibration Mode						
	Cylinder Value (ppmdv)	Calibration Response (ppmdv)	Difference from Cylinder Value	Difference (% of Calibration Span)			
Zero Gas	0.0	0.0	0.0				
Low-Range Gas	29.5	29.0	0.5	1.7%			
Mid-Range Gas	50.1	49.9	0.2	0.4%			
High-Range Gas	88.3	88.3	0.0	0.0%			
40 CFR 60 Method 25A-13.0							
Analyzer calibration error ≤5.0% of calibration gas value absolute difference							
Calibration Drift must be ≤3.0% of analyzer span absolute difference							
Upscale Gas: Mid 50.1 Analyzer Span: 100							
System Bias and Calibration Drift Assessments	Run	Analyzer Calibration Response (ppmdv)		Direct - System Difference	Pre - Post System Response	System Bias	Calibration Drift
Zero Gas	Pre	0.0	0.0	0.0			
Upscale Gas		49.9	50.0	0.1			
Zero Gas	1	0.0	0.0	0.0	0.0		0.0%
Upscale Gas		49.9	47.1	2.8	2.9		2.9%
Zero Gas	2	0.0	0.0	0.0	0.0		0.0%
Upscale Gas		49.9	50.5	0.6	3.4		3.4%
Zero Gas	3	0.0	0.5	0.5	0.5		0.5%
Upscale Gas		49.9	50.8	0.9	0.3		0.3%

Field Data

Client: Shell, PSR
Site: SRU4
Date: 07/27/11

Run: 1
Start Time: 12:00
End Time: 13:00

Table 3.1.1

Raw Emission Data:	O ₂	CO ₂	CO	Methane	Ethane	THC
Measurement Time	%	%	ppmdv	ppmdv	ppmdv	ppmv
12:01	3.51	8.78	90.8	0.0	0.1	0.25
12:02	3.53	8.76	88.3	-0.1	0.1	0.27
12:03	3.53	8.74	82.0	-0.1	0.2	0.24
12:04	3.46	8.79	69.0	-0.1	0.1	0.24
12:05	3.58	8.74	104.0	0.0	0.2	0.25
12:06	3.57	8.74	126.0	0.0	0.2	0.23
12:07	3.52	8.75	116.0	0.0	0.1	0.23
12:08	3.47	8.77	106.0	0.0	0.1	0.23
12:09	3.57	8.73	140.0	0.2	0.2	0.24
12:10	3.62	8.73	202.0	0.3	0.0	0.24
12:11	3.60	8.80	195.0	0.2	0.0	0.24
12:12	3.62	8.77	167.0	0.1	0.2	0.24
12:13	3.59	8.79	150.0	0.1	0.1	0.24
12:14	3.60	8.78	146.0	0.1	0.1	0.25
12:15	3.55	8.81	140.0	0.0	0.1	0.26
12:16	3.54	8.82	114.0	0.0	0.1	0.25
12:17	3.55	8.81	105.0	0.0	0.2	0.24
12:18	3.52	8.80	89.0	0.0	0.1	0.26
12:19	3.54	8.80	82.1	0.0	0.1	0.26
12:20	3.53	8.81	95.3	0.0	0.1	0.26
12:21	3.58	8.76	102.0	0.0	0.0	0.22
12:22	3.51	8.81	94.4	0.0	0.2	0.26
12:23	3.51	8.68	92.2	0.0	0.1	0.24
12:24	3.49	8.55	79.1	0.0	0.2	0.25
12:25	3.57	8.44	76.8	0.0	0.2	0.25
12:26	3.60	8.41	98.5	0.0	0.1	0.23
12:27	3.64	8.42	134.0	0.0	0.1	0.24
12:28	3.64	8.66	147.0	0.3	0.1	0.23
12:29	3.73	8.73	206.0	0.3	0.2	0.24
12:30	3.73	8.81	228.0	0.6	0.1	0.23
12:31	3.68	8.93	220.0	0.2	0.0	0.25
12:32	3.60	9.01	155.0	0.0	0.2	0.24
12:33	3.59	8.95	108.0	0.0	0.0	0.25
12:34	3.51	8.99	89.4	0.0	0.0	0.24
12:35	3.50	8.97	80.0	0.0	0.0	0.25
12:36	3.53	8.88	78.1	-0.1	0.2	0.26
12:37	3.48	8.90	81.1	0.0	0.1	0.25
12:38	3.56	8.82	88.3	0.0	0.2	0.25
12:39	3.60	8.83	118.0	0.1	0.2	0.26
12:40	3.55	8.88	130.0	0.0	0.0	0.25
12:41	3.54	8.85	110.0	0.0	0.1	0.25
12:42	3.53	8.79	102.0	0.0	0.1	0.25
12:43	3.56	8.77	120.0	0.0	0.1	0.24
12:44	3.58	8.83	132.0	0.1	0.2	0.24
12:45	3.67	8.81	155.0	0.2	0.1	0.23
12:46	3.71	8.79	160.0	0.1	0.1	0.26
12:47	3.71	8.80	150.0	0.0	0.1	0.24
12:48	3.70	8.81	119.0	0.0	0.1	0.24
12:49	3.68	8.84	102.0	0.0	0.2	0.24
12:50	3.66	8.89	86.6	0.0	0.0	0.25
12:51	3.65	8.88	73.7	-0.1	0.0	0.27
12:52	3.57	8.88	59.8	-0.1	0.1	0.25
12:53	3.56	8.85	51.8	-0.1	0.1	0.24
12:54	3.60	8.80	62.9	0.0	0.0	0.26
12:55	3.60	8.86	78.5	0.0	0.1	0.26
12:56	3.60	8.81	79.8	0.0	0.1	0.26
12:57	3.66	8.74	119.0	0.0	0.1	0.22
12:58	3.62	8.77	121.0	0.0	0.1	0.25
12:59	3.67	8.75	150.0	0.1	0.1	0.23
13:00	3.69	8.78	163.0	0.2	0.2	0.25
Raw Avg:	3.59	8.79	116.83	0.04	0.12	0.25
Bias Corrected Emissions:						
Average:	3.66	8.48	113.83	0.04	0.12	0.25

Field Data

Client: Shell, PSR
Site: SRU4
Date: 07/27/11

Run: 2
Start Time: 13:00
End Time: 14:00

Table 3.1.2

Raw Emission Data:	O ₂	CO ₂	CO	Methane	Ethane	THC
Measurement Time	%	%	ppmdv	ppmdv	ppmdv	ppmv
13:01	3.72	8.80	183.0	0.1	0.2	0.25
13:02	3.70	8.79	177.0	0.1	0.1	0.26
13:03	3.56	8.80	126.0	0.0	0.1	0.24
13:04	3.53	8.82	109.0	0.0	0.1	0.27
13:05	3.55	8.78	94.1	0.0	0.2	0.25
13:06	3.47	8.83	101.0	0.0	0.1	0.24
13:07	3.50	8.76	97.0	0.0	0.1	0.24
13:08	3.56	8.72	103.0	0.0	0.1	0.25
13:09	3.57	8.73	126.0	0.1	0.1	0.26
13:10	3.49	8.76	119.0	0.1	0.1	0.26
13:11	3.50	8.76	119.0	0.0	0.2	0.27
13:12	3.48	8.75	110.0	0.0	0.1	0.26
13:13	3.51	8.73	125.0	0.1	0.1	0.25
13:14	3.48	8.75	121.0	0.1	0.3	0.27
13:15	3.47	8.75	125.0	0.0	0.2	0.22
13:16	3.49	8.72	131.0	0.1	0.1	0.25
13:17	3.48	8.73	115.0	0.0	0.2	0.26
13:18	3.54	8.73	131.0	0.1	0.0	0.27
13:19	3.59	8.73	141.0	0.1	0.2	0.26
13:20	3.58	8.77	150.0	0.1	0.1	0.26
13:21	3.51	8.78	108.0	0.0	0.1	0.27
13:22	3.51	8.75	96.8	0.0	0.1	0.27
13:23	3.48	8.75	92.1	-0.1	0.1	0.26
13:24	3.45	8.71	74.4	0.0	0.1	0.25
13:25	3.46	8.72	83.8	0.0	0.1	0.27
13:26	3.45	8.77	85.4	-0.1	0.2	0.26
13:27	3.49	8.72	109.0	0.0	0.1	0.26
13:28	3.51	8.68	114.0	0.1	0.2	0.25
13:29	3.50	8.71	126.0	0.1	0.1	0.23
13:30	3.50	8.75	138.0	0.0	0.1	0.26
13:31	3.58	8.69	153.0	0.2	0.1	0.28
13:32	3.57	8.68	163.0	0.2	0.2	0.23
13:33	3.54	8.73	157.0	0.1	0.2	0.24
13:34	3.55	8.73	143.0	0.1	0.1	0.25
13:35	3.53	8.74	131.0	0.1	0.2	0.23
13:36	3.51	8.76	120.0	0.0	0.1	0.27
13:37	3.49	8.74	90.4	0.0	0.2	0.26
13:38	3.50	8.75	85.7	0.0	0.1	0.24
13:39	3.58	8.70	95.9	0.0	0.2	0.27
13:40	3.57	8.72	101.0	0.0	0.2	0.25
13:41	3.48	8.80	86.4	0.0	0.1	0.25
13:42	3.45	8.76	71.2	-0.1	0.1	0.26
13:43	3.44	8.74	70.2	0.0	0.1	0.25
13:44	3.46	8.70	78.0	0.0	0.1	0.25
13:45	3.51	8.69	89.7	0.0	0.1	0.26
13:46	3.53	8.69	129.0	0.1	0.1	0.27
13:47	3.51	8.72	125.0	0.1	0.1	0.27
13:48	3.48	8.71	122.0	0.0	0.2	0.27
13:49	3.48	8.71	125.0	0.0	0.2	0.27
13:50	3.46	8.71	120.0	0.0	0.2	0.25
13:51	3.39	8.74	102.0	0.0	0.2	0.27
13:52	3.45	8.70	97.6	0.0	0.3	0.26
13:53	3.48	8.71	118.0	0.0	0.2	0.26
13:54	3.50	8.70	129.0	0.1	0.2	0.24
13:55	3.44	8.71	117.0	0.0	0.1	0.24
13:56	3.49	8.65	102.0	0.0	0.2	0.27
13:57	3.46	8.69	119.0	0.0	0.2	0.26
13:58	3.42	8.67	121.0	0.0	0.2	0.26
13:59	3.35	8.64	88.0	0.0	0.2	0.26
14:00	3.38	8.66	112.0	0.1	0.2	0.27
Raw Avg:	3.50	8.73	114.88	0.03	0.15	0.26
Bias Corrected Emissions:						
Average:	3.58	8.39	111.69	0.03	0.15	0.26

Field Data

Client: Shell, PSR
Site: SRU4
Date: 07/27/11

Run: 3
Start Time: 14:56
End Time: 15:56

Table 3.1.3

Raw Emission Data:						
Measurement Time	O ₂ %	CO ₂ %	CO ppmdv	Methane ppmdv	Ethane ppmdv	THC ppmv
14:57	3.63	8.71	112.0	0.0	0.1	0.28
14:58	3.60	8.71	97.2	0.0	0.1	0.28
14:59	3.54	8.73	87.4	-0.1	0.1	0.28
15:00	3.51	8.74	92.6	0.0	0.2	0.28
15:01	3.52	8.68	92.7	-0.1	0.2	0.28
15:02	3.56	8.65	111.0	0.0	0.1	0.28
15:03	3.53	8.73	127.0	0.0	0.3	0.28
15:04	3.52	8.68	115.0	0.0	0.1	0.28
15:05	3.51	8.68	118.0	0.0	0.2	0.27
15:06	3.55	8.67	125.0	0.0	0.1	0.27
15:07	3.52	8.70	139.0	0.0	0.2	0.28
15:08	3.58	8.67	148.0	0.1	0.1	0.28
15:09	3.62	8.65	169.0	0.0	0.1	0.29
15:10	3.57	8.54	153.0	0.0	0.1	0.28
15:11	3.49	8.41	98.2	0.0	0.2	0.28
15:12	3.54	8.38	90.6	0.0	0.2	0.28
15:13	3.54	8.39	93.9	0.0	0.2	0.28
15:14	3.51	8.38	87.5	0.0	0.2	0.27
15:15	3.45	8.39	77.4	0.0	0.1	0.28
15:16	3.52	8.51	89.5	0.1	0.1	0.27
15:17	3.56	8.69	135.0	0.0	0.2	0.28
15:18	3.56	8.84	173.0	0.0	0.1	0.28
15:19	3.52	8.86	170.0	0.1	0.1	0.28
15:20	3.47	8.86	147.0	0.1	0.0	0.27
15:21	3.42	8.86	123.0	0.1	0.2	0.31
15:22	3.43	8.86	111.0	0.2	0.1	0.28
15:23	3.43	8.83	101.0	0.1	0.1	0.29
15:24	3.42	8.85	104.0	0.0	0.3	0.28
15:25	3.49	8.81	127.0	-0.1	0.1	0.28
15:26	3.55	8.75	134.0	0.0	0.2	0.28
15:27	3.52	8.81	143.0	0.0	0.3	0.28
15:28	3.47	8.86	121.0	0.0	0.2	0.28
15:29	3.43	8.86	93.3	0.0	0.2	0.28
15:30	3.41	8.82	71.8	-0.1	0.1	0.28
15:31	3.45	8.80	71.9	0.0	0.2	0.27
15:32	3.44	8.79	82.4	-0.1	0.2	0.28
15:33	3.43	8.78	79.2	0.0	0.2	0.27
15:34	3.46	8.72	75.9	-0.1	0.1	0.29
15:35	3.46	8.71	92.5	0.0	0.1	0.28
15:36	3.46	8.73	107.0	0.1	0.2	0.27
15:37	3.50	8.70	105.0	0.1	0.1	0.27
15:38	3.50	8.70	111.0	0.1	0.2	0.28
15:39	3.52	8.73	127.0	0.2	0.1	0.29
15:40	3.49	8.73	114.0	0.2	0.1	0.27
15:41	3.50	8.68	101.0	0.1	0.0	0.28
15:42	3.48	8.70	103.0	0.1	0.3	0.27
15:43	3.51	8.70	109.0	0.0	0.3	0.28
15:44	3.56	8.70	121.0	0.0	0.2	0.28
15:45	3.56	8.70	112.0	0.0	0.1	0.29
15:46	3.52	8.69	98.8	0.0	0.2	0.28
15:47	3.50	8.71	85.0	0.0	0.0	0.28
15:48	3.55	8.71	94.7	-0.1	0.1	0.29
15:49	3.51	8.74	103.0	0.1	0.2	0.28
15:50	3.47	8.72	88.5	0.0	0.0	0.28
15:51	3.43	8.69	72.8	0.0	0.2	0.27
15:52	3.43	8.66	86.7	0.0	0.1	0.28
15:53	3.47	8.65	103.0	0.1	0.1	0.27
15:54	3.46	8.65	117.0	0.0	0.2	0.27
15:55	3.49	8.66	144.0	0.1	0.3	0.28
15:56	3.44	8.67	136.0	0.1	0.0	0.29
Raw Avg:	3.50	8.70	110.33	0.02	0.15	0.28
Bias Corrected Emissions:						
Average:	3.59	8.40	107.55	0.02	0.15	0.03

Field Data

Table 4.0.0 Flows and Moisture Field Data

Raw Data Sheets

Flows and Moisture Field Data

Client: Shell, PSR	Date: 07/27/11
City: Anacortes, WA	
Site: SRU4	ETI Job No: 11-2084

Table 4.0

FIELD DATA:		Run Number		
		1	2	3
	START TIME:.....	12:00	12:00	12:00
	END TIME:.....	16:00	16:00	16:00
θ	Sample Time, minutes	240	240	240
	Stack Shape (Circle or Rectangle):	Circle		
V_m	Volume of dry gas sampled, ft ³	128.709	128.709	128.709
Y	Meter box calibration factor	1.0160	1.0160	1.0160
P_{bar}	Barometric pressure, inches Hg	30.16	30.16	30.16
P_{static}	Stack static pressure, inches H ₂ O	-1.00	-1.00	-1.00
ΔH	Differential meter press, inches H ₂ O	1.81	1.81	1.81
T_m	Meter temperature, degrees F	70.85	70.85	70.85
V_{lc}	Volume of H ₂ O collected, ml	325.40	325.40	325.40
%O₂	Percent of oxygen in stack gas	3.66	3.58	3.59
%CO₂	Percent carbon dioxide in stack gas	8.48	8.39	8.40
C_p	Type-S pitot tube coefficient	0.84	0.84	0.84
√ΔP_{avg}	Ave. square root of pitot readings, (inches H ₂ O) ^{1/2}	0.24924	0.24924	0.24924
T_s	Stack temperature, degrees F	1365.25	1365.25	1365.25
D_s	Stack diameter, feet - CIRCLE	4.83	4.83	4.83
L_s, W_s	Stack dimensions, feet - RECTANGLE	NA	NA	NA
D_n	Nozzle diameter, inches	0.49	NA	NA
A_n	Nozzle area, ft ²	NA	NA	NA
Calculated Values:				
V_{m(std)}	Meter corrected volume,dscf	131.688	131.688	131.688
V_{w(std)}	Volume of water vapor,dscf	15.343	15.343	15.343
B_{ws}	Fraction of H ₂ O vapor	0.104	0.104	0.104
B_{ws/sat}	Fraction of H ₂ O vapor at saturated conditions	456.05	456.05	456.05
%N₂	Percent nitrogen in stack gas	87.86	88.03	88.01
M_d	Dry molecular weight of stack gas, lb/lb-mole	29.50	29.49	29.49
M_w	Wet molecular weight of stack gas, lb/lb-mole	28.30	28.29	28.29
A_d	Cross sectional area of stack, ft ²	18.32	18.32	18.32
P_s	Absolute stack gas pressure, inches Hg	30.09	30.09	30.09
V_s	Average stack gas velocity, ft/sec	26.20	26.21	26.21
Q_{std}	Average stack volumetric flowrate, acfm	28,808	28,816	28,815
Q_{std}	Average stack volumetric flowrate, wscfm	8,380	8,382	8,382
Q_{std}	Average stack volumetric flowrate, dscfm	7,505	7,507	7,507
I	Percent isokinetic sampling	NA	NA	NA

Quality Assurance/Quality Control

ETI QA Document

Hand Calculations

Calibration Gas Certificates

Meter Calibrations

QUALITY ASSURANCE/QUALITY CONTROL

Emission Technologies, Inc. continued success is an example of their pride taken in quality testing.

Analytical procedures and environmental measurement data are structured with a quality assurance program which equals or exceeds the minimum QA/QC requirements set forth by the U.S. Environmental Protection Agency (EPA) for each applicable method.

ETI executes the following topics through every test project to ensure valid measurement data:

- * Preventable Maintenance
- * Pre-test and Post-test Calibration
- * Blanks and Spiked Samples
- * Field System Checks
- * QA/QC Matrix Tables
- * Employment of QA/QC Officer

The following table is an activity matrix for Method 8 from the EPA Quality Assurance Handbook for Air Pollution Measurement Systems. By diligently following such activity matrix tables, Emission Technologies, Inc. reports justifiable, valid measurement data.

TABLE 1.1 ACTIVITY MATRIX FOR PROCUREMENT OF APPARATUS & SUPPLIES

APPARATUS	ACCEPTANCE LIMITS	FREQUENCY AND METHOD OF MEASUREMENT	ACTION IF REQUIREMENTS ARE NOT MET
Sampling			
Sampling probe with heating system	Capable of 100° C (212° F) exit air at flow rate of 20 L/min	Visually check; run heating system checkout	Repair, return to supplier, or reject
Probe nozzle	Stainless steel (316); sharp, tapered, leading edge (angle ≤30°); difference between measured ID's ≤0.1 mm (0.004 in.); no nicks, dents, or corrosion; uniquely identified (Meth. 5, Sec. 3.4.2)	Visually check before each test; use a micrometer to measure ID before field use after each repair	Reshape and sharpen, return to the supplier, or reject
Pitot tube	Type-S (Meth. 2, Sec. 3.1.2); attached to probe with impact (high pressure) opening plane even with or above nozzle entry plane	Calibrate according to Meth. 2, Sec. 3.1.2	Repair or return to supplier

TABLE 1.1 (CONTINUED)

APPARATUS	ACCEPTANCE LIMITS	FREQUENCY AND METHOD OF MEASUREMENT	ACTION IF REQUIREMENTS ARE NOT MET
Differential pressure gauge (manometer)	Criteria in Meth. 2, Sec. 3.1.2; agree within 5% of gauge-oil manometer used to calibrate	Check against gauge-oil manometer at a minimum of three points: [0.64(0.025), 12.7(0.5), 25.4(1.0)] mm (in.) H ₂ O	As above
Vacuum gauge	0-760 mm Hg range; ± 25 mm (1 in.) Hg accuracy at 380 mm (15 in.) Hg	Check against a mercury U-tube manometer upon receipt	Adjust or return to supplier
Vacuum pump	Capable of maintaining a flow rate of 0.03-0.05 m ³ /min (1-1.7 ft ³ /min) for pump inlet vacuum of 380 mm (15 in.) Hg with pump outlet at 760 mm (29.92 in.) Hg; leak free at 380 mm (15 in.) Hg	Check upon receipt for leaks and capacity	Repair or return to supplier
Orifice meter	ΔH @ of 46.74 \pm 6.35 mm (1.84 \pm 0.25 in.) (recommended)	Visually check upon receipt for damage; calibrate against wet test meter	Repair, if possible; otherwise, return to supplier
Impingers	Standard stock glass; pressure drop across impingers not excessive	Visually check upon receipt; check pressure drop (Method 8, Sec. 3.7.1)	Return to supplier
Filter holder	Leak free (Method 8, Sec. 3.7.1)	Visually check before use	As above
Filters	Glass fiber without organic binder designed to remove 99.95% ($\leq 0.05\%$ penetration) of 0.3- μ m dioctyl phthalate smoke particles	Manufacturer's guarantee that filters meet ASTM standard method D2986-71; observe under light for defects	Return to supplier and replace

TABLE 1.1 (CONTINUED)

APPARATUS	ACCEPTANCE LIMITS	FREQUENCY AND METHOD OF MEASUREMENT	ACTION IF REQUIREMENTS ARE NOT MET
Hydrogen peroxide	30% H ₂ O ₂ reagent grade or certified ACS	Upon receipt, check label for grade or certification	Replace or return to supplier
Potassium iodide	KI reagent grade or certified ACS	As above	As above
Thorin indicator	1-(o-arsonophenylazo)-2-naphthol-3,6 disulfonic acid disodium salt, reagent grade or certified ACS	Upon receipt, check label for grade or certification	As above
Barium perchlorate trihydrate solution	Ba(ClO ₄) ₂ · 3H ₂ O, - reagent grade or certified ACS	As above	As above
Sulfuric acid solution	H ₂ SO ₄ , 0.0100N ± 0.0002N	Certified by manufacturer, or standardize against 0.0100N NaOH previously standardized against potassium acid phthalate (primary standard grade)	As above
NO_x Chemiluminescence Analyzer	NO _x to NO conversion efficiency ≥ 90%	Before each field test; Introduce a concentration of 40-60 ppm NO ₂ to the analyzer in direct cal mode; Calculate converter efficiency: $\text{Eff}_{\text{NO}_2} = \frac{C_{\text{Dir}}}{C_{\text{V}}} \times 100$	Repair

HAND CALCULATIONS

CLIENT: Shell

SITE LOCATION: SR44

PROJECT #: 11-2084

Nomenclature:

- A_d = cross-sectional area of stack, ft^2
 A_n = cross-sectional area of nozzle, ft^2
 B_{ws} = water vapor in the gas stream, proportion by volume
 C_p = pitot tube coefficient, dimensionless
 D_s = diameter of stack, ft^2
 K_p = pitot tube constant = $85.49 \text{ ft/sec} \sqrt{\frac{(\text{lb/lb-mole})(\text{inches Hg})}{(^{\circ}\text{R})(\text{inches H}_2\text{O})}}$
 M_d = molecular weight of stack gas, dry basis, lb./lb.-mole
 M_w = molecular weight of stack gas, wet basis, lb./lb.-mole
 $\quad = M_d(1 - B_{ws}) + 18(B_{ws})$
 ΔH = differential meter pressure, inches H_2O
 $\sqrt{\Delta P_{avg}}$ = average velocity head of stack gas, $\sqrt{\text{inches H}_2\text{O}}$
 $\% \text{CO}_2$ = percent by volume of carbon dioxide in stack gas
 $\% \text{N}_2$ = percent by volume of nitrogen in stack gas
 $\% \text{O}_2$ = percent by volume of oxygen in stack gas
 P_{bar} = barometric pressure, inches Hg
 P_s = absolute stack gas pressure, inches Hg
 P_{static} = static pressure of the stack, inches H_2O
 P_{std} = standard absolute pressure, 29.92 inches Hg
 Q_{std} = stack flow rate, dscfm or dscfh
 T_m = meter temperature, $^{\circ}\text{F}$
 T_{std} = standard absolute temperature, 528°R
 $T_{s(avg)}$ = Absolute stack temperature, $^{\circ}\text{R} = 460 + T_s$
 V_m = meter volume, ft^3
 V_{mstd} = corrected meter volume, dscf
 V_s = average stack gas velocity, ft/sec
 V_{lc} = volume of water gain in the impingers, ml or grams

 Y = dry gas meter calibration factor
13.6 = specific gravity of mercury

Volume of metered sample gas at standard conditions:

$$P_{\text{meter}} = P_{\text{bar}} + \frac{\Delta H}{13.6} = \frac{30.16}{13.6} + \frac{1.81}{13.6} = \underline{30.293085} \text{ inches Hg}$$

$$V_{\text{m(std)}} = \frac{(V_{\text{m}}) \times (T_{\text{std}}) \times (P_{\text{meter}}) \times (Y)}{(T_{\text{m}} + 460) \times (P_{\text{std}})}$$

$$V_{\text{m(std)}} = \frac{(128.709) \times (528) \times (30.293085) \times (1.016)}{(70.85 + 460) \times (29.92)} = \underline{131.688147} \text{ dscf}$$

Moisture Content:

$$V_{\text{w(std)}} = (0.04715 \text{ ft}^3/\text{gram water}) \times (V_{\text{lc}}) \quad 1 \text{ gram water} \equiv 1 \text{ ml water}$$

$$V_{\text{w(std)}} = (0.04715) \times (325.4) = \underline{15.34261} \text{ scf}$$

$$B_{\text{ws}} = \frac{V_{\text{w(std)}}}{(V_{\text{w(std)}} + V_{\text{m(std)}})}$$

$$B_{\text{ws}} = \frac{15.34261}{(15.34261 + 131.688147)} = \underline{0.1043497} \text{ water vapor fraction}$$

Molecular Weight:**Percent Nitrogen in Stack Gas**

$$\%N_2 = 100\% - \%O_2 - \%CO_2$$

$$\%N_2 = 100 - (3.66) - (8.48) = \underline{87.86} \text{ percent } N_2$$

Dry:

$$M_{\text{d}} = (0.44 \times \%CO_2) + (0.32 \times \%O_2) + (0.28 \times \%N_2)$$

$$M_{\text{d}} = (0.44 \times 8.48) + (0.32 \times 3.66) + (0.28 \times 87.86) = \underline{29.5032} \text{ lb/lb-mole}$$

Wet:

$$M_{\text{w}} = M_{\text{d}} \times (1 - B_{\text{ws}}) + (18 \times B_{\text{ws}})$$

$$M_w = (\underline{29.5032}) \times (1 - \underline{0.10434966}) + (18 \times \underline{0.10434966}) = \underline{28.302845} \text{ lb/lb-mole}$$

Average Velocity of Stack Gas:

$$V_s = K_p \times C_p \times \sqrt{\Delta P_{avg}} \times \sqrt{\frac{T_{s(avg)}}{M_w \times P_s}} \quad P_s = P_{bar} + \frac{P_{static}}{13.6}$$

$$P_s = (\underline{30.16}) + \frac{(\underline{-1.0})}{13.6} = \underline{30.0864706}$$

$$V_s = 85.49 \times \underline{0.84} \times \underline{0.24924} \times \sqrt{\frac{(1365.25 + 460)}{\underline{28.302845} \times \underline{30.0864706}}} = \underline{26.2043177} \text{ ft/sec}$$

Volume Flow Rate:

$$A_d = \pi \times \frac{(D_s)^2}{4}$$

$$A_d = 3.14159 \times \frac{(\underline{4.83})^2}{4} = \underline{18.3224597} \text{ ft}^2$$

$$Q_{std} = 60 \times (1 - B_{ws}) \times V_s \times A_d \times \frac{T_{std} \times P_s}{T_{s(avg)} \times P_{std}}$$

$$Q_{std} = 60 \times (1 - \underline{0.10434966}) \times \underline{26.2043177} \times \underline{18.3224597} \times \frac{528 \times (\underline{30.0864706})}{(\underline{1365.25} + \underline{460}) \times 29.92} = \underline{7505.29} \text{ dscfm}$$

System Bias Calibrations

$$C_{\text{gas}} = \frac{(C - C_0)}{(C_m - C_0)} \times C_{\text{ma}}$$

where: C_{gas} = gas concentration, dry basis ppm

C = average gas concentration indicated by the analyzer

C_0 = average of initial and final system bias responses for the zero gas

C_m = average of initial and final system bias responses for the upscale gas

C_{ma} = actual concentration of the upscale calibration gas, ppm

Gas: O₂

$$C_0 = \frac{(C_{\text{pre-zero}} + C_{\text{post-zero}})}{2} = \frac{(0.0 + 0.02)}{2} = 0.01$$

$$C_m = \frac{(C_{\text{pre-span}} + C_{\text{post-span}})}{2} = \frac{(12.38 + 12.28)}{2} = 12.33$$

$$C_{\text{gas}} = \frac{(3.586 - 0.01)}{(12.33 - 0.01)} \times 12.0 = 3.6572727$$

Gas: CO₂

$$C_0 = \frac{(0.00 + 0.04)}{2} = 0.05 \quad C_m = \frac{(12.68 + 12.78)}{2} = 12.73$$

$$C_{\text{gas}} = \frac{(8.7875 - 0.05)}{(12.73 - 0.05)} \times 12.3 = 8.47565$$

Gas: CO

$$C_0 = \frac{(0.8 + 0.2)}{2} = 0.5 \quad C_m = \frac{(488 + 492)}{2} = 490$$

$$C_{\text{gas}} = \frac{(116.825 - 0.5)}{(490 - 0.5)} \times 479 = 113.829775$$

Gas: THC

$$C_0 = \frac{(0.0 + 0.0)}{2} = 0.0 \quad C_m = \frac{(50.0 + 47.1)}{2} = 48.55$$

$$C_{\text{gas}} = \frac{(0.245467 - 0.0)}{(48.55 - 0.0)} \times 50.1 = 0.2533034$$

PPM Adjusted for H₂O

$$C_{\text{ppmdv}} = \frac{C_{\text{ppmwv}}}{(1 - B_{\text{ws}})}$$

where: C_{ppmdv} = gas concentration, dry basis ppm

C_{ppmwv} = gas concentration, wet basis ppm

THC

$$C_{\text{ppmdv}} = \frac{(0.2533034)}{(1 - 0.10434966)} = \underline{0.2828151}$$

CH₄

$$C_{\text{ppmdv}} = \frac{(0.0395042)}{(1 - 0.10434966)} = \underline{0.0441067}$$

C₂H₆

$$C_{\text{ppmdv}} = \frac{(0.1173604)}{(1 - 0.10434966)} = \underline{0.1310337}$$

Conversion from ppm to lbs/dscf

$$C_d = C_{\text{ppm}} \times C_F \quad (\text{example for CO: } 7.255 \times 10^{-8}, \text{ see below})$$

$$\text{CO: } C_d = (113.829775) \times 7.255 \times 10^{-8} = \underline{8.258 \times 10^{-6}}$$

$$\text{CH}_4: C_d = (0.0441067) \times 4.154 \times 10^{-8} = \underline{1.83 \times 10^{-9}}$$

$$\text{C}_2\text{H}_6: C_d = (0.13103376) \times 7.79 \times 10^{-8} = \underline{1.021 \times 10^{-8}}$$

$$\text{THC: } C_d = (0.2828151) \times 1.142 \times 10^{-7} = \underline{3.23 \times 10^{-8}}$$

Conversion from lbs/dscf to lbs/hour

$$E_i = C_d \times Q_{std} \times 60$$

$$\text{CO: } E_i = (8.258 \times 10^{-6}) \times (7505.292) \times 60 = \underline{3.71888} \text{ lb/hr}$$

$$\text{CH}_4: E_i = (1.83 \times 10^{-9}) \times (7505.292) \times 60 = \underline{0.0008251} \text{ lb/hr}$$

$$\text{C}_2\text{H}_6: E_i = (1.021 \times 10^{-8}) \times (7505.292) \times 60 = \underline{0.00459663} \text{ lb/hr}$$

$$\text{THC: } E_i = (3.23 \times 10^{-8}) \times (7505.292) \times 60 = \underline{0.014544} \text{ lb/hr}$$

Where: Q_{std} = flow rate in standard dry cubic ft per hr
60 is to convert minutes to hours

C_F is calculated as follows:

2.59×10^{-9} x component molecular weight for English units, lb/dscf

lb/dscf Air Molecular Weight = 28.95 lb/lb-mole

Air Density = 0.075 lb/ft³ (at 68°F)

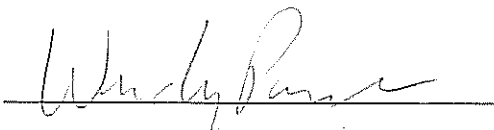
MW = pollutant molecular weight, lb/lb-mole

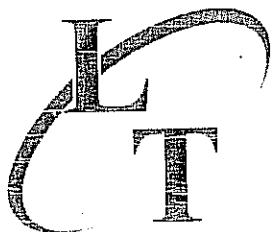
10^{-6} to convert density to lb/ft³/ppm

$$\text{density} = \frac{MW \times 0.075}{28.95} \times 10^{-6}$$

Parameter	C_F
CO	0.7255×10^{-7}
NO _x	1.194×10^{-7}
SO ₂	1.660×10^{-7}
VOC @ Methane	0.4154×10^{-7}
VOC @ Ethane	0.779×10^{-7}
THC @ Propane	1.142×10^{-7}

Technician Signature





LIQUID TECHNOLOGY CORPORATION

"INDUSTRY LEADER IN SPECIALTY GASES"

Certificate of Analysis

- EPA PROTOCOL GAS -

**** Re-certification ****

<u>Customer</u>	<u>Emission Technologies, Inc (Burlington, WA)</u>
<u>Date</u>	<u>January 06, 2011</u>
<u>Delivery Receipt</u>	<u>DR-31884</u>
<u>Gas Standard</u>	<u>60.0 - 90.0 ppm Hydrogen Sulfide/Nitrogen - EPA PROTOCOL</u>
<u>Final Analysis Date</u>	<u>January 06, 2011</u>
<u>Expiration Date</u>	<u>January 06, 2012</u>

DO NOT USE BELOW 150 psig

Analytical Data:

EPA Protocol, Section No. 2.2, Procedure G-1.

Replicate Concentrations

Hydrogen Sulfide: 73.8 ppm +/- 0.73 ppm

Nitrogen: Balance

Reference Standards

SRM/GMIS:	GMIS	GMIS
Cylinder Number:	CC-125529	CC-231527
Concentration:	50.7 ppm Hydrogen Sulfide/N2	110.2 ppm Hydrogen Sulfide/Nitrogen
Expiration Date:	May 09, 2011	November 21, 2011

Certification Instrumentation

Component:	Hydrogen Sulfide
Make/Model:	InterScan RM-17-1
Serial Number:	718700
Principal of Measurement:	ElectroChemical
Last Calibration:	December 03, 2010

Cylinder Data

Cylinder Number:	CC-184314	Cylinder Volume:	119 Cubic Feet
Cylinder Outlet:	CGA 330	Cylinder Pressure:	1700 psig, 70°F
Expiration Date:	January 06, 2012		

Analytical Uncertainty and NIST Traceability are in compliance with EPA-600/R-97/121.

Certified by:

Mike Duncan

Original Date:

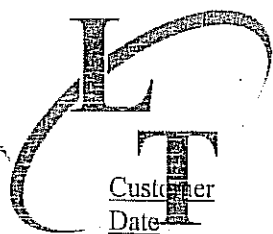
ppm H2S/Nitrogen (November 09, 2009)

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Customer

Date

Delivery Receipt

Gas Standard

Final Analysis Date

Expiration Date

Emission Technologies, Inc (Burlington, WA)

December 23, 2010

DR-31678

12.0-13.0% CO₂, 12.0-13.0% Oxygen/Nitrogen-EPA PROTOCOL

December 14, 2010

December 14, 2013

DO NOT USE BELOW 150 psig

Cylinder Data

Cylinder Serial Number:

CC-184281

Cylinder Outlet:

CGA 590

Cylinder Volume:

136 Cubic Feet

Cylinder Pressure:

1950 psig, 70°F

Expiration Date:

December 14, 2013

Analytical Data

EPA Protocol, Section No. 2.2, Procedure G-1

Replicate Concentrations

Carbon Dioxide: 12.3% +/- 0.12%

Oxygen: 12.6% +/- 0.12%

Nitrogen: Balance

Reference Standard(s):

GMIS/SRM:

GMIS/GMIS

GMIS/GMIS

Cylinder Number:

CC-165377/CC-125534

CC-231332/CC-85458

Concentration:

9.924% CO₂/13.21% CO₂

10.1% Oxygen/20.97% O₂/Nitrogen

Expiration Date:

04/06/11 - 04/01/11

03/04/11 - 04/15/11

Certification Instrumentation

Component:

Carbon Dioxide

Oxygen

Make/Model:

Horiba - VIA 510

Servomex 244a

Serial Number:

SN075GSF

1847

Principal of Measurement:

NDIR

Paramagnetic

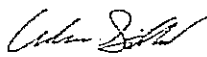
Last Calibration:

December 03, 2010

December 03, 2010

Analytical uncertainty and NIST Traceability are in compliance with EPA-600/R-97/121.

Certified by:


Adam Strickland

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Liquid Technology Corporation

Industry Leader in Specialty Gases, Equipment and Service

Certificate of Analysis - EPA PROTOCOL GAS -

<u>Customer</u>	<u>Emission Technologies, Inc (Burlington, WA)</u>
<u>Date</u>	<u>April 28, 2010</u>
<u>Delivery Receipt</u>	<u>DR-29131</u>
<u>Gas Standard</u>	<u>21.5% CO₂, 21.5% Oxygen/Nitrogen-EPA PROTOCOL</u>
<u>Final Analysis Date</u>	<u>April 19, 2010</u>
<u>Expiration Date</u>	<u>April 19, 2013</u>

DO NOT USE BELOW 150 psig

<u>Cylinder Data</u>		
Cylinder Serial Number:	<u>CC-79739</u>	Cylinder Outlet: <u>CGA 590</u>
Cylinder Volume:	<u>140 Cubic Feet</u>	Cylinder Pressure: <u>2000 psig, 70°F</u>
Expiration Date:	<u>April 19, 2013</u>	

Analytical Data

EPA Protocol, Section No. 2.2, Procedure G-1

Replicate Concentrations
Carbon Dioxide: 21.1% +/- 0.21%
Oxygen: 21.9% +/- 0.21%
Nitrogen: Balance

Reference Standard(s):

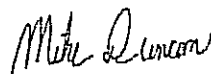
GMIS/SRM:	GMIS/GMIS	GMIS
Cylinder Number:	CC-115915/158974	CC-85458
Concentration:	19.44% CO ₂ /39.86% CO ₂	20.97% Oxygen/Nitrogen
Expiration Date:	12/31/11 - 03/17/12	04/15/11

Certification Instrumentation

Component:	Carbon Dioxide	Oxygen
Make/Model:	Agilent 7890A	Servomex 244a
Serial Number:	CN10736166	1847
Principal of Measurement:	GC-TCD	Paramagnetic
Last Calibration:	March 26, 2010	March 22, 2010

Analytical uncertainty and NIST Traceability are in compliance with EPA-600/R-97/121.

Certified by:



Mike Duncan

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"INDUSTRY LEADER IN SPECIALTY GASES"



Certificate of Analysis **- EPA PROTOCOL GAS -**

Customer

Date

Delivery Receipt

Gas Standard

Final Analysis Date

Expiration Date

Emission Technologies, Inc (Burlington, WA)

December 23, 2010

DR-31678

12.0-13.0% CO₂, 12.0-13.0% Oxygen/Nitrogen-EPA PROTOCOL

December 14, 2010

December 14, 2013

DO NOT USE BELOW 150 psig

Cylinder Data

Cylinder Serial Number:

CC-252024

Cylinder Outlet:

CGA 590

Cylinder Volume:

136 Cubic Feet

Cylinder Pressure:

1950 psig, 70°F

Expiration Date:

December 14, 2013

Analytical Data

EPA Protocol, Section No. 2.2, Procedure G-1

Replicate Concentrations
Carbon Dioxide: 12.3% +/- 0.12%
Oxygen: 12.6% +/- 0.12%
Nitrogen: Balance

Reference Standard(s):

GMIS/SRM:

GMIS/GMIS

GMIS/GMIS

Cylinder Number:

CC-165377/CC-125534

CC-231332/CC-85458

Concentration:

9.924% CO₂/13.21% CO₂

10.1% Oxygen/20.97% O₂/Nitrogen

Expiration Date:

04/06/11 - 04/01/11

03/04/11 - 04/15/11

Certification Instrumentation

Component:

Carbon Dioxide

Oxygen

Make/Model:

Horiba - VIA 510

Servomex 244a

Serial Number:

SN075GSF

1847

Principal of Measurement:

NDIR

Paramagnetic

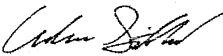
Last Calibration:

December 03, 2010

December 03, 2010

Analytical uncertainty and NIST Traceability are in compliance with EPA-600/R-97/121.

Certified by:


Adam Strickland

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Certificate of Analysis

- EPA PROTOCOL GAS -

Customer

Emission Technologies, Inc. (Burlington, WA)

Date

December 06, 2010

Delivery Receipt

DR-31559

Gas Standard

50.0 ppm SO₂, 50.0 ppm NO, 50.0 ppm CO/Nitrogen-EPA PROTOCOL

Final Analysis Date

November 30, 2010

Expiration Date

November 30, 2012

DO NOT USE BELOW 150 psig

Analytical Data:

EPA Protocol, Section No. 2.2, Procedure G-1.

Reported Concentrations:

Sulfur Dioxide: 48.1 ppm +/- 0.48 ppm

Nitric Oxide: 50.9 ppm +/- 0.50 ppm

Carbon Monoxide: 48.9 ppm +/- 0.48 ppm

Nitrogen: Balance

Total NOx: 51.2 ppm

** Total NOx for Reference Use Only **

Reference Standards

SRM/GMIS

GMIS/GMIS

GMIS

GMIS

Cylinder Number:

CC-93923/CC-233310

CC-184190

CC-159042

Concentration:

25.02/53.29 ppm SO₂

49.07 ppm NO

50.84 ppm CO

Expiration Date:

02/09/12 - 09/20/12

09/20/12

10/20/12

Certification Instrumentation

Component:

Sulfur Dioxide

Nitric Oxide

Carbon Monoxide

Make/Model:

Nicolet - NEXUS 470

Nicolet - NEXUS 470

Nicolet-NEXUS 470

Serial Number:

AEP99000154

AEP99000154

AEP99000154

Principal of Measurement:

FTIR

FTIR

FTIR

Last Calibration:

November 01, 2010

November 02, 2010

November 02, 2010

Cylinder Data

Cylinder Number:

CC-185221

Cylinder Volume: 136 Cubic Feet

Cylinder Outlet:

CGA 660

Cylinder Pressure: 1950 psig, 70°F

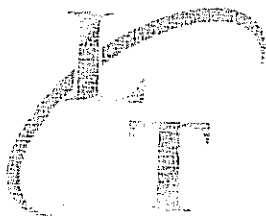
Analytical Uncertainty and NIST Traceability are in compliance with EPA-600/R-97/121.

Certified by:

Adam Strickland

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Certificate of Analysis
- EPA PROTOCOL GAS -

<u>Customer</u>	<u>Emission Technologies, Inc (Burlington, WA)</u>
<u>Date</u>	<u>February 22, 2011</u>
<u>Delivery Receipt</u>	<u>DR-32327</u>
<u>Gas Standard</u>	<u>95.0 ppm NO, 95.0 ppm SO₂, 95.0 ppm CO/Nitrogen - EPA PROTOCOL</u>
<u>Final Analysis Date</u>	<u>February 22, 2011</u>
<u>Expiration Date</u>	<u>February 22, 2013</u>

DO NOT USE BELOW 150 psig

Analytical Data:
EPA Protocol, Section No. 2.2, Procedure G-1.

Reported Concentrations
Nitric Oxide: 92.9 ppm +/- 0.92 ppm
Sulfur Dioxide: 96.9 ppm +/- 0.96 ppm
Carbon Monoxide: 94.0 ppm +/- 0.94 ppm
Nitrogen: Balance
Total NOx: 93.1 ppm
** Total NOx for Reference Use Only **

Reference Standards

SRM/GMIS:	GMIS	GMIS	GMIS
Cylinder Number:	CC-85467	XX-13579	CC-129043
Concentration:	99.97 ppm NO	104.03 ppm SO ₂	105.88 ppm CO
Expiration Date:	09/15/12	12/01/12	10/21/12

Certification Instrumentation

Component:	Nitric Oxide	Sulfur Dioxide	Carbon Monoxide
Make/Model:	Nicolet - NEXUS 470	Nicolet - NEXUS 470	Nicolet - NEXUS 470
Serial Number:	AEP99000154	AEP99000154	AEP99000154
Principal of Measurement:	FTIR	FTIR	FTIR
Last Calibration:	February 03, 2011	February 03, 2011	February 03, 2011

Cylinder Data

Cylinder Number:	CC-251932	Cylinder Volume:	133 Cubic Feet
Cylinder Outlet:	CGA 660	Cylinder Pressure:	1900 psig, 70°F
Expiration Date:	February 22, 2013		

Analytical Uncertainty and NIST Traceability are in compliance with EPA-600/R-97/121.

Certified by:

Adam Strickland

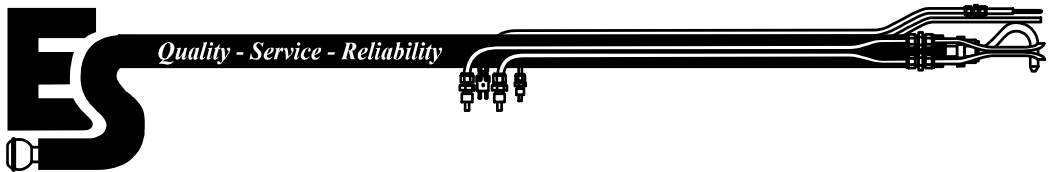
<u>Replicate Data:</u>	<u>NO</u>	<u>SO₂</u>	<u>CO</u>
	02/15/11: 92.7, 92.7, 92.8 ppm	97.1, 97.0, 97.0 ppm	94.0, 93.9, 93.9 ppm
	02/22/11: 93.1, 92.9, 93.1 ppm	96.7, 96.8, 96.7 ppm	94.1, 94.0, 94.3 ppm

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METHOD 5 DRY GAS METER CALIBRATION USING CRITICAL ORIFICES

- 1) Select three critical orifices to calibrate the dry gas meter which bracket the expected operating range.
- 2) Record barometric pressure before and after calibration procedure.
- 3) Run at tested vacuum (from Orifice Calibration Report), for a period of time necessary to achieve a minimum total volume of 5 cubic feet.
- 4) Record readings in outlined boxes below, other columns are automatically calculated.



DATE: 7/21/2011		METER SERIAL #: 1695387		BAROMETRIC PRESSURE (in Hg):		INITIAL 29.74	FINAL 29.74	AVG (P _{bar}) 29.74		IF Y VARIATION EXCEEDS 2.00%, ORIFICE SHOULD BE RECALIBRATED									
METER PART #: HF-D		CRITICAL ORIFICE SET SERIAL #: 1545s																	
ORIFICE #	RUN #	K' FACTOR (AVG)	TESTED VACUUM (in Hg)	DGM READINGS (FT ³)			TEMPERATURES °F					ELAPSED TIME (MIN) θ	DGM ΔH (in H ₂ O)	(1) V _m (STD)	(2) V _{cr} (STD)	(3) Y	Y VARIATION (%)	ΔH _@	
				INITIAL	FINAL	NET (V _m)	AMBIENT	DGM INLET		DGM OUTLET									DGM AVG
12	1	0.3165	22	755.950	761.177	5.227	59	62	62	62	62	62	13.00	0.54	5.2633	5.3728	1.021	0.5	1.79
	2	0.3165	22	761.177	766.414	5.237	59	62	63	62	63	62.5	13.00	0.54	5.2683	5.3728	1.020		1.79
	3	0.3165	22	766.414	771.641	5.227	59	63	63	63	63	63	13.00	0.54	5.2532	5.3728	1.023		1.79
																AVG =	1.021		
16	1	0.443	21.5	774.650	779.662	5.012	62	64	64	63	64	63.75	9.00	1.1	5.0369	5.1914	1.031	-2.19	1.87
	2	0.443	21.5	779.662	784.690	5.028	62	64	65	64	64	64.25	9.00	1.1	5.0482	5.1914	1.028		1.87
	3	0.443	21.5	784.690	790.303	5.613	62	65	65	64	64	64.5	9.00	1.1	5.6328	5.1914	0.922		1.87
																AVG =	0.994		
19	1	0.5155	21	732.405	737.50	5.095	60	59	60	58	60	59.25	8.00	1.5	5.1698	5.3801	1.041	2.81	1.89
	2	0.5155	21	737.50	742.604	5.104	60	60	61	60	60	60.25	8.00	1.5	5.1690	5.3801	1.041		1.89
	3	0.5155	21	742.604	747.668	5.064	59	61	62	60	61	61	8.00	1.5	5.1211	5.3852	1.052		1.88
																AVG =	1.044		
24	1	0.6497	19	796.10	801.697	5.597	62	66	67	65	65	65.75	7.00	2.2	5.6186	5.9217	1.054	-4.16	1.74
	2	0.6497	19	801.697	808.931	7.234	60	67	68	65	66	66.5	7.00	2.2	7.2516	5.9331	0.818		1.73
	3	0.6497	19	808.931	814.575	5.644	61	68	68	66	66	67	7.00	2.2	5.6523	5.9274	1.049		1.73
																AVG =	0.974		
31	1	0.8453	16	828.0	833.237	5.237	61	70	71	67	67	68.75	5.00	3.8	5.2479	5.5085	1.050	3.02	1.76
	2	0.8453	16	833.237	838.486	5.249	61	71	71	67	67	69	5.00	3.8	5.2575	5.5085	1.048		1.76
	3	0.8453	16	838.486	843.763	5.277	61	71	71	67	67	69	5.00	3.8	5.2855	5.5085	1.042		1.76
																AVG =	1.047		

USING THE CRITICAL ORIFICES AS CALIBRATION STANDARDS:

The following equations are used to calculate the standard volumes of air passed through the DGM, V_m (std), and the critical orifice, V_{cr} (std), and the DGM calibration factor, Y. These equations are automatically calculated in the spreadsheet above.

AVERAGE DRY GAS METER CALIBRATION FACTOR, Y = 1.016

AVERAGE ΔH_@ = 1.81

(1)
$$Vm_{(std)} = K_1 * Vm * \frac{Pbar + (\Delta H / 13.6)}{Tm}$$
 = Net volume of gas sample passed through DGM, corrected to standard conditions
K₁ = 17.64 °R/in. Hg (English), 0.3858 °K/mm Hg (Metric)
T_m = Absolute DGM avg. temperature (°R - English, °K - Metric)

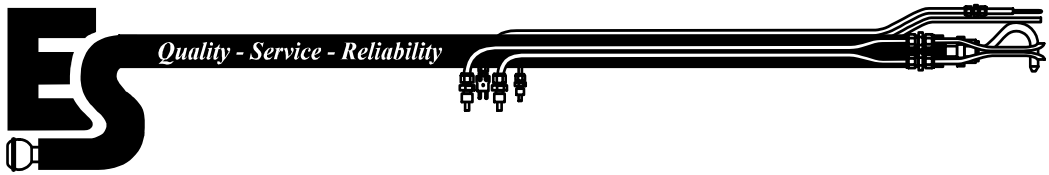
(2)
$$Vcr_{(std)} = K' * \frac{Pbar * \Theta}{\sqrt{Tamb}}$$
 = Volume of gas sample passed through the critical orifice, corrected to standard conditions
T_{amb} = Absolute ambient temperature (°R - English, °K - Metric)
K' = Average K' factor from Critical Orifice Calibration

(3)
$$Y = \frac{Vcr_{(std)}}{Vm_{(std)}}$$
 = DGM calibration factor

$$\Delta H_{@} = \left(\frac{0.75 \theta}{V_{cr}(std)} \right)^2 \Delta H \left(\frac{V_m(std)}{V_m} \right)$$

METHOD 5 DRY GAS METER CALIBRATION USING CRITICAL ORIFICES

- 1) Select three critical orifices to calibrate the dry gas meter which bracket the expected operating range.
- 2) Record barometric pressure before and after calibration procedure.
- 3) Run at tested vacuum (from Orifice Calibration Report), for a period of time necessary to achieve a minimum total volume of 5 cubic feet.
- 4) Record readings in outlined boxes below, other columns are automatically calculated.



DATE: 8/2/2011		METER SERIAL #: 1695387		BAROMETRIC PRESSURE (in Hg):		INITIAL	FINAL	AVG (P _{bar})	IF Y VARIATION EXCEEDS 2.00%, ORIFICE SHOULD BE RECALIBRATED									
METER PART #: HF-D		CRITICAL ORIFICE SET SERIAL #: 1545s				29.89	29.89	29.89										
ORIFICE #	RUN #	K' FACTOR (AVG)	TESTED VACUUM (in Hg)	DGM READINGS (FT ³)			TEMPERATURES °F					ELAPSED TIME (MIN) θ	DGM ΔH (in H ₂ O)	(1) V _m (STD)	(2) V _{cr} (STD)	(3) Y	Y VARIATION (%)	ΔH@
				INITIAL	FINAL	NET (V _m)	AMBIENT	DGM INLET		DGM OUTLET								
	1					.0						0			AVG =			
	2					.0						0						
	3					.0						0						
	1					.0						0			AVG =			
	2					.0						0						
	3					.0						0						
16	1	0.443	21.5	774.650	779.492	4.842	62	64	64	63	64	63.75	8.50	1.05	4.8899	4.9277	1.008	1.77
	2	0.443	21.5	779.492	784.346	4.854	62	64	65	64	64	64.25	8.50	1.05	4.8974	4.9277	1.006	1.77
	3	0.443	21.5	784.346	789.183	4.837	62	65	65	64	64	64.5	8.50	1.05	4.8779	4.9277	1.010	1.77
AVG =																1.008	0.00	1.77
	1					.0						0			AVG =			
	2					.0						0						
	3					.0						0						
	1					.0						0			AVG =			
	2					.0						0						
	3					.0						0						
AVG =																		

USING THE CRITICAL ORIFICES AS CALIBRATION STANDARDS:

The following equations are used to calculate the standard volumes of air passed through the DGM, V_m (std), and the critical orifice, V_{cr} (std), and the DGM calibration factor, Y. These equations are automatically calculated in the spreadsheet above.

(1)

$$Vm_{(std)} = K_1 * Vm * \frac{Pbar + (\Delta H / 13.6)}{Tm}$$

= Net volume of gas sample passed through DGM, corrected to standard conditions
K₁ = 17.64 °R/in. Hg (English), 0.3858 °K/mm Hg (Metric)
T_m = Absolute DGM avg. temperature (°R - English, °K - Metric)

(2)

$$Vcr_{(std)} = K' * \frac{Pbar * \Theta}{\sqrt{Tamb}}$$

= Volume of gas sample passed through the critical orifice, corrected to standard conditions
T_{amb} = Absolute ambient temperature (°R - English, °K - Metric)
K' = Average K' factor from Critical Orifice Calibration

(3)

$$Y = \frac{Vcr_{(std)}}{Vm_{(std)}}$$

= DGM calibration factor

AVERAGE DRY GAS METER CALIBRATION FACTOR, Y = 1.008

AVERAGE ΔH_@ = 1.77

$$\Delta H_{@} = \left(\frac{0.75 \theta}{V_{cr}(std)} \right)^2 \Delta H \left(\frac{V_m(std)}{V_m} \right)$$

Meter Box Temperature Read-out Checks
Date: 7/11/2011 Calibrator: DJW

Read out ID	Meter Box #	Set Temp.	Box Temp.	Set Temp.	Box Temp.	Set Temp.	Box Temp.	% Diff.	% Diff.	% Diff.
Main #1	HF-I	250	252	125	125	68	68	-0.38241	0	0
Main #2	HF-I	250	252	125	125	68	68	-0.38241	0	0
Main #3	HF-I	250	252	125	125	68	68	-0.38241	0	0
Main #4	HF-I	250	252	125	125	68	67	-0.38241	0	0.293255
Probe	HF-I	250	249	125	124	68	68	0.191205	0.251256	0
Filter	HF-I	250	250	125	125	68	69	0	0	-0.29326
Main #1	HF-M	250	252	125	125	68	67	-0.38241	0	0.293255
Main #2	HF-M	250	253	125	125	68	68	-0.57361	0	0
Main #3	HF-M	250	253	125	125	68	68	-0.57361	0	0
Main #4	HF-M	250	251	125	124	68	68	-0.1912	0.251256	0
Main #5	HF-M	250	253	125	126	68	68	-0.57361	-0.25126	0
Probe	HF-M	250	251	125	126	68	71	-0.1912	-0.25126	-0.87977
Filter	HF-M	250	252	125	126	68	69	-0.38241	-0.25126	-0.29326
Main #1	HF-E	250	251	125	126	68	68	-0.1912	-0.25126	0
Main #2	HF-E	250	251	125	126	68	69	-0.1912	-0.25126	-0.29326
Main #3	HF-E	250	251	125	126	68	69	-0.1912	-0.25126	-0.29326
Main #4	HF-E	250	251	125	126	68	68	-0.1912	-0.25126	0
Main #5	HF-E	250	251	125	126	68	68	-0.1912	-0.25126	0
Probe	HF-E	250	251	125	126	68	68	-0.1912	-0.25126	0
Filter	HF-E	250	251	125	126	68	68	-0.1912	-0.25126	0
Main #1	HF-B	250	249	125	126	68	71	0.191205	-0.25126	-0.87977
Main #2	HF-B	250	249	125	126	68	72	0.191205	-0.25126	-1.17302
Main #3	HF-B	250	249	125	127	68	71	0.191205	-0.50251	-0.87977
Main #4	HF-B	250	249	125	126	68	71	0.191205	-0.25126	-0.87977
Main #5	HF-B	250	251	125	126	68	71	-0.1912	-0.25126	-0.87977
Probe	HF-B	250	252	125	127	68	70	-0.38241	-0.50251	-0.58651
Filter	HF-B	250	250	125	125	68	68	0	0	0
Main #1	HF-D	250	257	125	124	68	64	-1.33843	0.251256	1.173021
Main #2	HF-D	250	258	125	124	68	64	-1.52964	0.251256	1.173021
Main #3	HF-D	250	257	125	124	68	63	-1.33843	0.251256	1.466276
Main #4	HF-D	250	255	125	122	68	62	-0.95602	0.753769	1.759531
Main #5	HF-D	250	256	125	122	68	62	-1.14723	0.753769	1.759531
Main #6	HF-D	250	256	125	122	68	63	-1.14723	0.753769	1.466276
Probe	HF-D	250	252	125	125	68	68	-0.38241	0	0
Filter	HF-D	250	252	125	125	68	63	-0.38241	0	1.466276
Main #1	HF-J	250	251	125	126	68	65	-0.1912	-0.25126	0.879765
Main #2	HF-J	250	251	125	127	68	65	-0.1912	-0.50251	0.879765
Main #3	HF-J	250	251	125	127	68	66	-0.1912	-0.50251	0.58651
Main #4	HF-J	250	251	125	126	68	65	-0.1912	-0.25126	0.879765
Probe	HF-J	250	251	125	125	68	65	-0.1912	0	0.879765
Filter	HF-J	250	251	125	125	68	65	-0.1912	0	0.879765
Main #1	LF-3-1598D	250	252	125	125	68	66	-0.38241	0	0.58651
Main #2	LF-3-1598D	250	252	125	126	68	66	-0.38241	-0.25126	0.58651
Main #3	LF-3-1598D	250	252	125	126	68	66	-0.38241	-0.25126	0.58651
Main #4	LF-3-1598D	250	253	125	126	68	67	-0.57361	-0.25126	0.293255
Probe	LF-3-1598D	250	252	125	126	68	67	-0.38241	-0.25126	0.293255
Filter	LF-3-1598D	250	252	125	126	68	66	-0.38241	-0.25126	0.58651