UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
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SEATTLE, WA 98101

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Exhibit No. :	C-406
Air Permit Name:	Shell Kulluk
File Category:	C - Correspondence and Communication Between EPA and Shell (Including Shell Contractors)

2011-05-06 - Attachments to Email from Tim Martin, Air Sciences, Inc., to Doug Hardesty, EPA, Regarding Shell Items from April 7th Modelers Call

- To EPA - 04192011

Original files can be found on the Shell Kulluk Administrative Record Compact Disc.

Chukchi Sea Exploration Drilling Program – Shell Gulf of Mexico, Inc.
Beaufort Sea Exploration Drilling Program – Shell Offshore, Inc.

2010 M/V Discoverer Air Emissions Testing

Starboard Deck Crane Engine (D-15)

Job Number: 10-1822
August 24, 2010

Performed and Reported by:

Emission Technologies, Inc.
15609-D Peterson Rd.
Burlington, WA 98233
(360) 757-1210 FAX (360) 757-1118
(800) 507-9018 / eti@stacktester.com

For submittal to:

Shell Exploration and Production
3601 C Street, Suite 1000
Anchorage, Alaska 99503

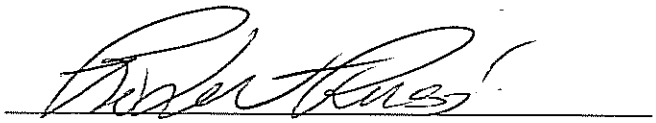
Submitted On:

May 3, 2011

REVIEW AND CERTIFICATION

Team Leader:

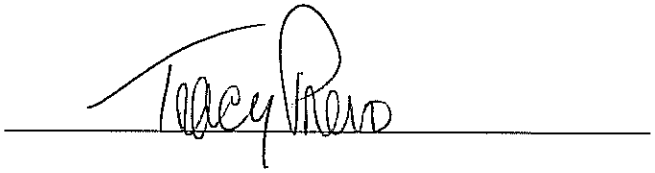
The work performed herein was conducted under my supervision, and I certify that the details and results contained within this report are, to the best of my knowledge, an authentic and accurate representation of the test program. If this report is submitted for compliance purposes it should only be reproduced in its entirety. If there are any questions concerning this report, please contact the Team Leader or Reviewer at (360) 757-1210.



Robert Rusi
Operations Manager

Reviewer:

I have reviewed this report for presentation and accuracy of content, and hereby certify that, to the best of my knowledge, the information is complete and correct.



Tracy Prevo
Quality Assurance Manger

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INTRODUCTION

Test Purpose

Emission Technologies, Inc. (ETI) was contracted by Shell Gulf of Mexico Inc. and Shell Offshore Inc. (hereafter to be referred to collectively as "Shell"), to conduct source testing on the Discoverer Drillship and several of the vessels that will support the Discoverer (the "Associated Fleet"). EPA issued a Prevention of Significant Deterioration (PSD) air quality permit for Shell's exploration in the Chukchi Sea on March 31, 2010 (R10CS/PSD-AK-09-01) and for Shell's exploration in the Beaufort Sea on April 9, 2010 (R10OCS/PSD-AK-2010-01). Although requests for review of both of these permits were made to the Environmental Appeals Board (and remand of both permits has subsequently been directed by that Board), Shell submitted to EPA source test protocols, test schedules, and a request for modification of two test procedures. This test report addresses exhaust emissions from the cranes on the M/V Discoverer Drillship (the D), which is a potential drilling rig. This testing was performed in Subic Bay, Philippines in August 2010.

The D is equipped with 6 generators for the ship's electrical needs, 3 MLC compressor engines, 2 HPU engines, 2 deck crane engines, 3 cementing unit engines, 2 logging winches, 2 boilers and 1 incinerator. The emission unit covered by this report is the Starboard Deck Crane Engine (D-15) identified in Table 1.0.

Emissions tests were conducted to determine the concentration and emission rates of oxygen (O_2), carbon dioxide (CO_2), oxides of nitrogen (NO_x), carbon monoxide (CO) and volatile organic compounds (VOC) along with the stack gas visible emissions (Opacity), velocity (V_s), moisture (B_{ws}) and volumetric flow rate (Q_{std}).

Table 1.0
Emission Unit – M/V Discoverer

Unit	Manufacturer	Model	Serial Number
D-15	Caterpillar	D-343	62B13125

Test Location

The testing was conducted on the outlet stack of the Starboard Deck Crane Engine while in the Halliburton Test Unit facility in Duncan, Oklahoma. Stack gases were directed to an operating CleanAIR Systems catalyzed diesel particulate filter (CDPF) while testing was conducted.

Test Date(s)

The one hundred percent (280 horsepower) and fifty percent load (225 horsepower) tests were performed on August 24, 2010.

Parameters Tested

The parameters and test methods used during the test program are summarized in Table 1.1. The parameters were determined or measured using U.S. Environmental Protection Agency (EPA) test methods that are provided in Title 40, Part 60 (40CFR60), Appendix A of the Code of Federal Regulations (CFR), and in the Sampling Analysis Procedures section of this report.

Table 1.1
Testing Protocol for D-15 Starboard Deck Crane Engine

Parameter	Test Method	# of Test Runs	Time
O_2, CO_2, Moisture	EPA Methods 1-4	3 Runs per Load	60 minutes
NO_x - Outlet	EPA Method 7E	3 Runs per Load	60 minutes
CO - Outlet	EPA Method 10	3 Runs per Load	60 minutes
Opacity	EPA Method 9	30 Runs per Load	6 minutes
VOC - Outlet	EPA Method 25A	3 Runs per Load	60 minutes

Table 1.2
D-15 Starboard Deck Crane Engine Loads Tested

Unit	Parameter	Test Load	# of Units
D-15	NO_x, CO & VOC	100% Load	1 Unit
	NO_x, CO, VOC & Opacity	50% Load	1 Unit

- Starboard Deck Crane Engine was tested at above loads as measured by a dynamometer

Sampling Personnel

Robert Rusi, David Worgum, David Wagner, Thomas Franett, Carey Mott, Paige Mendoza and Richard Brennan with ETI performed the testing. Mr. Keith Craik with Shell coordinated the test program.

Even though the testing program was not for compliance purposes, the EPA was provided a test plan and notified of the testing at least 30 days in advance. No representative of the EPA was present during testing.

Other Important Background Information

The D utilizes a Caterpillar diesel-fired reciprocating direct-drive internal combustion engine rated at 365 horsepower (hp). Testing on the D-15 Starboard Deck Crane Engine was conducted at the Halliburton Test Unit facility in Duncan, Oklahoma.

Chukchi Sea Exploration Drilling Program – Shell Gulf of Mexico, Inc.
Beaufort Sea Exploration Drilling Program – Shell Offshore, Inc.

2010 M/V Discoverer Air Emissions Testing

Heat Boiler (D-21)

Job Number: 10-1822
October 4, 2010

Performed and Reported by:

Emission Technologies, Inc.
15609-D Peterson Rd.
Burlington, WA 98233
(360) 757-1210 FAX (360) 757-1118
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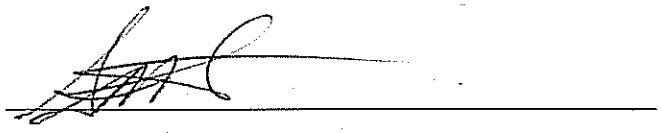

Scott Chesnut
Senior Project Manager

Reviewer:

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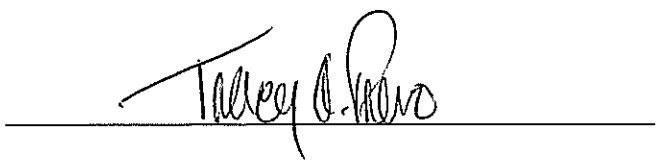

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The D is equipped with 6 generators for the ship's electrical needs, 3 MLC compressor engines, 2 HPU engines, 2 deck crane engines, 3 cementing unit engines, 2 logging winches, 2 boilers and 1 incinerator. The emission unit covered by this report is the Heat Boiler (D-21) identified in Table 1.0.

Emissions tests were conducted to determine the concentration and emission rates of oxygen (O_2), carbon dioxide (CO_2), particulate matter (PM), oxides of nitrogen (NO_x), carbon monoxide (CO) and volatile organic compounds (VOC) along with the stack gas visible emissions (Opacity), velocity (V_s), moisture (B_{ws}) and volumetric flow rate (Q_{std}).

Table 1.0
Emission Unit – M/V Discoverer

Unit	Manufacturer	Model	Serial Number
D-21	Clayton	200	-

Test Location

The testing was conducted on the outlet stack of the Heat Boiler while the D was in Keppel Shipyard in Singapore.

Test Date(s)

The one hundred percent and the fifty percent load tests were performed on October 4, 2010.

Parameters Tested

The parameters and test methods used during the test program are summarized in Table 1.1. The parameters were determined or measured using U.S. Environmental Protection Agency (EPA) test methods that are provided in Title 40, Part 60 (40CFR60), Appendix

A of the Code of Federal Regulations (CFR), and in the Sampling Analysis Procedures section of this report.

Table 1.1
Testing Protocol for D-21 Heat Boiler

Parameter	Test Method	# of Test Runs	Time
O_2, CO_2, Moisture	EPA Methods 1-4	3 Runs per Load	60 minutes
PM*	EPA Methods 5/202	3 Runs per Load	60 minutes
NO_x - Outlet	EPA Method 7E	3 Runs per Load	60 minutes
CO - Outlet	EPA Method 10	3 Runs per Load	60 minutes
Opacity	EPA Method 9	30 Runs per Load	6 minutes
VOC - Outlet	EPA Method 25A	3 Runs per Load	60 minutes

* Note: In a letter from EPA, dated May 24, 2010, Richard Albright with EPA's Office of Air, Waste and Toxics, accepted Shell's proposed amendment to the testing protocol, to measure total particulate (Method 5) in lieu of PM_{10} and $PM_{2.5}$ (Methods 201/201A).

Table 1.2
D-21 Heat Boiler Loads Tested

Unit	Parameter	Test Load	# of Units
Heat Boiler	NO_x, CO, VOC, PM* & Opacity	100% Load	1 Unit
	NO_x and PM*	50% Load	1 Unit

Sampling Personnel

Scott Chesnut, David Worgum, Danny Dizon, Thomas Franett, Carey Mott, Collin Wardell, Adam Manning, Mike Scullywest, Gary Dubrall and Richard Brennan with ETI performed the testing. Mr. Keith Craik with Shell coordinated the test program.

Even though the testing program was not for compliance purposes, the EPA was provided a test plan and notified of the testing at least 30 days in advance. No representative of the EPA was present during testing.

Other Important Background Information

The D utilizes a Clayton Heat Boiler rated at 7.97 million British Thermal Units of Heat Input per hour (MMBtu/hr). Testing on the D-21 Heat Boiler was conducted at the Keppel Shipyard facility in Singapore, Singapore.

SUMMARY OF RESULTS

Units of Emission Measurements

The results of the D-21 air emissions tests are summarized in Section 2, Tables 2.0.1-2.1.2.

NO_x, CO and VOC test results are presented in concentration units of dry parts per million by volume (ppmdv), emission rate units of pounds per hour (lbs/hr) and emission factor units of pounds per gallon of fuel (lb/gal fuel) and pounds per million British Thermal Units of Heat Input (lbs/MMBtu). VOC was measured as total organic carbon (TOC) and reported as dry propane

PM test results are reported in concentration units of grams per dry standard cubic meter (g/dscm) and grains per dry standard cubic feet (grains/dscf), emission rate units of lb/hr and emission factor units of lb/gal fuel and lb/MMBtu.

Diluent O_2 and CO_2 test results are presented in units of dry percent by volume (%). Volumetric Flow Rate test results are presented in units of dry standard cubic meter per minute (dscm/m) and dry standard cubic feet per minute (dscf/m).

The D-21 was equipped with two fuel meters to measure fuel consumption and return to the day tank. The ship's operational data was electronically recorded at 5-minute intervals, throughout the source test. Printouts of the ship's operational data were provided and are included in Appendix E. Fuel data was the operational data collected.

Comments: Discussion of Quality Assurance and Errors

Quality assurance procedures listed in the above referenced test methods and referenced in the Quality Assurance Project Plan were performed and documented. The QA/QC procedures are described in the Method Description, Equipment, Sampling, Analysis and QA/QC sections of the report. Documentation of the QA/QC is provided in Appendix F.

The NO_x analyzer converter efficiency was confirmed to be within specifications in accordance with RM 7E Section 16.2 and can be found in Appendix F.

Laboratory analysis of the fuel used while running these tests showed the sulfur content to be less than the 15 ppm requirement for classification as ultra low sulfur diesel. The laboratory report for the fuel analysis can be found in Appendix B.

SOURCE OPERATION

Source and Process Description

The D-21 Heat Boiler is a Clayton model 200 rated at 7.97 MMBtu/hr.

Pollution Control Equipment

There is no pollution control equipment on this unit.

Flow Diagram

A drawing of the stack exhaust is contained in Appendix G.

Process and Control Operating Parameters During Testing

Average fuel consumption was recorded and provided to ETI and referenced in Table 6.0.2 and 6.1.2.

Operating Conditions

During the test program, the D-21 was operated as close as possible to 100% and 50% of the maximum intended operating load, based on fuel usage.

Shell has:

- The D-21 is equipped with 2 diesel fuel flow meters.
- The fuel flow meters are located as close as practical to the fuel intake of the boiler.
- The fuel flow meters are totalizing and non-resettable.

Testing or Process Interruptions and Changes

There were no interruptions or delays during the test program.

SAMPLING AND ANALYSIS PROCEDURES

Sample Port Location

Emissions from the D-21 outlet stack were sampled via two horizontally mounted ports located on the circular stack exit. The two sample ports are located 90 degrees apart.

The ports are located greater than 6 inside stack diameters downstream from the nearest flow disturbance and greater than 2 inside stack diameters upstream from the stack exit. The minimum number of sample points required is ten per port (20 total). The stack exit height is approximately 70 feet above the water line.

A diagram of the outlet stack is contained in Appendix G.

Point Description/Labeling – Ports/Stack

The stack's ports were not labeled, but were designated as left and right, as looking from the sample probe, for testing purposes. Particulate samples were collected from 20 sample points. Velocity traverses were performed at 20 sample points. Moisture tests were performed for 60 minutes.

A three-point gaseous stratification check was performed prior to testing. There was no stratification present in the exhaust gas stream; therefore a single point was used for the remainder of gas sampling.

Method Description, Equipment, Sampling, Analysis and QA/QC

Sampling and analytical procedures of the EPA Methods were followed as published in the "Quality Assurance Handbook for Air Pollution Measurement Systems" Volume III, US EPA 600/4-77-027b.

EPA Method 1 - Sample and Velocity Traverses for Stationary Sources

EPA Method 1 is 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 is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. A traverse point is 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 is determined from the gas density and from measurement of the average velocity head with a Type S (Stausscheibe 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 is extracted at a constant rate and then condensed and metered using an EPA Method 5 sample train. The weight gain of moisture condensed is determined gravimetrically by measuring the weight change of the impingers.

EPA Methods 3A, 7E and 10 – Determination of Gas Concentrations

The testing methodology for O_2, CO_2, NO_x and CO concentrations in the flue gas consist of a continuously operated gas analyzer system. Sample gases are first extracted from the stack through a heated probe/glass fiber filter assembly. A calibration gas purge valve is fitted ahead of the filter assembly for introducing calibration gases to the analyzer system. The samples are transported through Teflon sample lines to a portable unit containing the analyzers. Each of the samples is conditioned while a constant sample extraction rate is maintained. The analyzers detect the concentration of analyte gas within the sample and produce an electrical output signal proportional to analyte gas concentration. The electrical signal is recorded simultaneously on a digital DAS.

Instrument calibrations (zero and span checks) are performed per Method 7E. Sampling system calibrations and linearity determinations are 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 were constructed of 316 stainless steel, Viton O-rings, and a Teflon coated diaphragm.

Table 1.4

Parameter	Limits
Instrument Linearity	± 2% of calibration span
Instrument Bias	± 5% of calibration span
Calibration Gas	± 2% of calibration span
NO_x Converter Efficiency	≥ 90% of certified gas concentration
Instrument Zero Drift	± 3% of calibration span
Instrument Span Drift	± 3% of calibration span

EPA Method 5/202 - Determination of Particulate and Condensable Particulate Matter

Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature in the range of 248 ± 25°F (120 ± 14°C). The sample volume collected was at least 30 dscf per run. Particulate matter that is deposited on the nozzle, probe and front half of the filter holder is rinsed with acetone and collected in a sample bottle. The acetone is then evaporated off at the laboratory and desiccated for 24

hours. The particulate mass from the rinse and filter are determined gravimetrically after removal of uncombined water.

The condensable particulate matter (CPM), back half fraction, is the material that condenses after passing through the filter and is analyzed using Method 202. The method uses a Method 5 sampling train with the addition of a condenser, a water dropout impinger and a modified Greenburg Smith impinger (both dry) followed by a Teflon CPM filter. The potential artifacts from SO_2 are reduced using a condenser and dropout impinger to separate CPM from reactive gases. To improve the collection efficiency of CPM, an additional filter (the CPM filter) is placed between the second and third impingers. The impinger contents are immediately purged after the run for one hour with nitrogen to remove dissolved sulfur dioxide gases. The CPM filter is extracted with water and methylene chloride. The impingers are recovered, rinsed and the organic and aqueous fractions are separated using methylene chloride. The organic and aqueous fractions are then taken to dryness and residues weighed. The total of both fractions represents the CPM.

EPA Method 9 – Visual Determination of Opacity

This method involves the determination of plume opacity by qualified observers. The method includes procedures for the training and certification of observers and procedures to be used in the field for determination of plume opacity. The opacity of emissions from stationary sources is determined at the point of greatest opacity in that portion of the plume where water vapor is not present. The observer does not look at the plume continuously, but instead observes the plume momentarily at 15-second intervals. Opacity is determined as an average of 24 consecutive observations recorded at 15-second intervals. A set is composed of any 24 consecutive observations. Sets need not be consecutive in time and no two sets can overlap.

EPA Method 25A – Determination of VOC 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). The concentration is expressed in terms of propane (or other appropriate organic calibration gas) or in terms of carbon. The sampled gases were continuously extracted from the stack through a heated probe/filter assembly and a heated Teflon line to a mobile test trailer containing a flame ionization analyzer (FIA) gas analyzer. 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 strip chart recorder and DAS. A calibration error test was performed immediately prior to the test. Calibration drift tests were performed following each run or hourly if continuous sampling 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 or as carbon equivalents.

For the measurement of non-methane hydrocarbons (NMHC) an FIA with a methane cutter was used. The analyzer controls the flow of gas sample into the chromatographic column. As the sample was carried down the column, the various components moved at different speeds, as determined by their physical and chemical properties. Due to its low molecular weight and high volatility, methane moved faster than other organic compounds and was the first to emerge from the opposite end of the column. Upon leaving the column, the methane flowed back through a rotary valve and then to the flame ionization detector (FID). Once the methane peak was detected, the rotary valve returned to its original back-flush position. The NMHC's were back-flushed out and carried to the FID for measurement. Time required for analysis of one sample was about 70 seconds. Calibration was done using methane (2 ppm and up, balance nitrogen). The readout showed three values (methane, nonmethane and total) and held for 70 seconds.

Nomenclature

A_d = cross-sectional area of stack, m^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

ΔH = differential orifice meter pressure, mm H_2O or inches H_2O

ΔP = stack gas velocity pressure, mmH_2O or inches H_2O

$\sqrt{\Delta P}_{avg}$ = average of square roots of ΔP, $\sqrt{\text{mm } H_2O}$, $\sqrt{\text{inches } H_2O}$

D_s = diameter of stack, ft^2

F_{Btu} = fuel heating value, gross Btu/lb or gross Btu/gal

F_{den} = fuel density, kg/liter or lb/gal

F_{grv} = fuel API specific gravity

F_{O2} = F factor for dry effluent, used with percent O_2, dscf/MMBtu

I = percent isokinetic sampling rate

K_p = pitot tube constant = 34.97 m/sec $\sqrt{\frac{(\text{g / g – mole})(\text{mm Hg})}{(^{o}\text{K})(\text{mm } H_2O)}}$

K_5 = isokinetic rate constant, 4.32 for metric units; 0.0945 for English units

M_b = mass of field train total cpm blank, g

M_c = mass of NH_4^+ added to sample to form ammonium sulfate, g

M_{cpm} = mass of condensable particulate matter

M_d = molecular weight of stack gas, dry basis, g/g-mole

M_i = mass of inorganic cpm, g

M_o = mass of organic cpm, g

M_w = molecular weight of stack gas, wet basis, g/g-mole, $M_d (1- B_{ws)} + 18(B_{ws})$

N = normality of ammonium hydroxide titrant

$\%CO_2$ = percent by volume of carbon dioxide in stack gas

$\%N_2$ = percent by volume of nitrogen in stack gas

$\%O_2$ = percent by volume of oxygen in stack gas

P_{bar} = barometric pressure, mm Hg or inches Hg

P_s = absolute stack gas pressure, mm Hg or inches Hg

P_{static} = static pressure of the stack, mm Hg or inches H_2O

P_{std} = standard absolute pressure, 29.92 inches Hg or 760 mm Hg

Q_f = fuel flow rate, liter/hr or gal/hr

Q_{std} = stack flow rate, dscm/m or dscf/min

θ = sample time, minutes

T_m = meter temperature, ^{o}C or ^{o}F

T_s = average stack temperature, ^{o}C or ^{o}F

T_{std} = standard absolute temperature, $528^{o}R$ or $293^{o}K$

$T_{s(avg)}$ = Average absolute stack temperature, $^{o}K = 273 + T_s$ (^{o}F)

V_{lc} = weight of water gain in the impingers, g

V_{mstd} = corrected meter volume, dscm

V_S = average stack gas velocity, m/sec.

V_t = volume of NH_4OH titrant, ml

Y = dry gas meter calibration factor

SUMMARIES

100% LOAD

50% LOAD

Summary Gases

Client	Shell	**Date:**	10/04/10
City:	Singapore	**Boiler Make:**	Clayton
ETI Job No:	10-1822	**Boiler Model:**	200
Site:	Discoverer	**Boiler Serial Number:**	-
Unit:	D-21	**Load:**	100%

Table 2.0.1

Start Time:	**9:54**	**11:23**	**12:50**	
End Time:	**10:53**	**12:22**	**13:49**	
Fuel Data	**Run Number**			**Average**
	1	**2**	**3**	
gal/hr	57.0	57.0	57.0	**57**
MMBtu/hr	7.8	7.8	7.8	**8**
Stack Parameters	**Run Number**			**Average**
	1	**2**	**3**	
% Moisture	11.4	11.1	11.8	**11.4**
M-1-4 Q_{std}, scfm	1,345	1,306	1,313	**1,321**
O_2	**Run Number**			**Average**
	1	**2**	**3**	
Percent	5.1	5.0	5.0	**5.0**
CO_2	**Run Number**			**Average**
	1	**2**	**3**	
Percent	11.3	11.4	11.4	**11.4**
NO_x	**Run Number**			**Average**
	1	**2**	**3**	
ppmdv	88.6	87.8	95.5	**90.6**
lbs/hr	0.85	0.82	0.90	**0.86**
lb/gal fuel	0.015	0.014	0.016	**0.015**
lb/MMBtu	0.11	0.11	0.12	**0.11**
CO	**Run Number:**			
	1	**2**	**3**	**Average**
ppmdv	40.9	44.2	41.9	**42.3**
lb/hr	0.239	0.251	0.239	**0.243**
lb/gal fuel	0.00419	0.00440	0.00419	**0.00426**
lb/MMBtu	0.0306	0.0322	0.0306	**0.0311**
VOC	**Run Number:**			
	1	**2**	**3**	**Average**
ppmwv	0.00	0.10	0.26	**0.12**
ppmdv	0.00	0.11	0.29	**0.13**
lb/hr	0.0000	0.0010	0.0026	**0.0012**
lb/gal fuel	0.000000	0.000018	0.000046	**0.000021**
lb/MMBtu	0.00000	0.00013	0.00033	**0.00015**

D-21 & 22 NO_x: 0.20 lbs/MMBtu; CO: 0.0770 lbs/MMBtu; VOC: 0.00140 lb/MMBtu

Chukchi Sea Exploration Drilling Program – Shell Gulf of Mexico, Inc.
Beaufort Sea Exploration Drilling Program – Shell Offshore, Inc.

2010 M/V Discoverer Air Emissions Testing

Heat Boiler (D-22)

Job Number: 10-1822
October 5, 2010

Performed and Reported by:

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3601 C Street, Suite 1000
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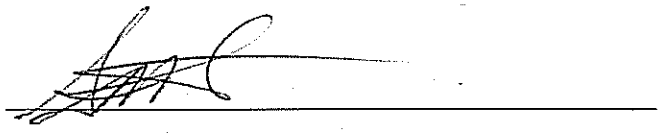
Team Leader:

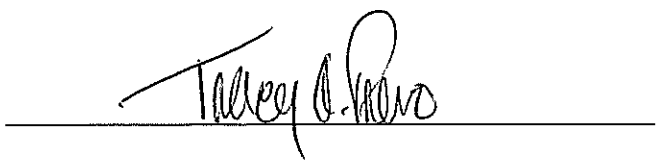
The work performed herein was conducted under my supervision, and I certify that the details and results contained within this report are, to the best of my knowledge, an authentic and accurate representation of the test program. If this report is submitted for compliance purposes it should only be reproduced in its entirety. If there are any questions concerning this report, please contact the Team Leader or Reviewer at (360) 757-1210.



Scott Chesnut
Senior Project Manager

Reviewer:

I have reviewed this report for presentation and accuracy of content, and hereby certify that, to the best of my knowledge, the information is complete and correct.



Tracy Prevo
Quality Assurance Manger

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APPENDICES

INTRODUCTION

Test Purpose

Emission Technologies, Inc. (ETI) was contracted by Shell Gulf of Mexico Inc. and Shell Offshore Inc. (hereafter to be referred to collectively as "Shell"), to conduct source testing on the Discoverer Drillship and several of the vessels that will support the Discoverer (the "Associated Fleet"). EPA issued a Prevention of Significant Deterioration (PSD) air quality permit for Shell's exploration in the Chukchi Sea on March 31, 2010 (R10CS/PSD-AK-09-01) and for Shell exploration in the Beaufort Sea on April 9, 2010 (R10OCS/PSD-AK-2010-01). Although requests for review of both of these permits were made to the Environmental Appeals Board (and remand of both permits has subsequently been directed by that Board), Shell's submitted to EPA source test protocols, test schedules, and a request for modification of two test procedures. This test report addresses exhaust emissions from the boilers on the M/V Discoverer Drillship (the D), which is a potential drilling rig. This testing was performed in Singapore in October 2010.

The D is equipped with 6 generators for the ship's electrical needs, 3 MLC compressor engines, 2 HPU engines, 2 deck crane engines, 3 cementing unit engines, 2 logging winches, 2 boilers and 1 incinerator. The emission unit covered by this report is the Heat Boiler (D-22) identified in Table 1.0.

Emissions tests were conducted to determine the concentration and emission rates of oxygen (O_2), carbon dioxide (CO_2), particulate matter (PM), oxides of nitrogen (NO_x), carbon monoxide (CO) and volatile organic compounds (VOC) along with the stack gas visible emissions (Opacity), velocity (V_s), moisture (B_{ws}) and volumetric flow rate (Q_{std}).

Table 1.0
Emission Unit – M/V Discoverer

Unit	Manufacturer	Model	Serial Number
D-22	Clayton	200	-

Test Location

The testing was conducted on the outlet stack of the Heat Boiler while the D was in Keppel Shipyard in Singapore.

Test Date(s)

The one hundred percent and the fifty percent load tests were performed on October 5, 2010.

Parameters Tested

The parameters and test methods used during the test program are summarized in Table 1.1. The parameters were determined or measured using U.S. Environmental Protection

Agency (EPA) test methods that are provided in Title 40, Part 60 (40CFR60), Appendix A of the Code of Federal Regulations (CFR), and in the Sampling Analysis Procedures section of this report.

Table 1.1
Testing Protocol for D-22 Heat Boiler

Parameter	Test Method	# of Test Runs	Time
O_2, CO_2, Moisture	EPA Methods 1-4	3 Runs per Load	60 minutes
PM*	EPA Methods 5/202	3 Runs per Load	60 minutes
NO_x - Outlet	EPA Method 7E	3 Runs per Load	60 minutes
CO - Outlet	EPA Method 10	3 Runs per Load	60 minutes
Opacity	EPA Method 9	30 Runs per Load	6 minutes
VOC - Outlet	EPA Method 25A	3 Runs per Load	60 minutes

* Note: In a letter from EPA, dated May 24, 2010, Richard Albright with EPA's Office of Air, Waste and Toxics, accepted Shell's proposed amendment to the testing protocol, to measure total particulate (Method 5) in lieu of PM_{10} and $PM_{2.5}$ (Methods 201/201A).

Table 1.2
D-22 Heat Boiler Loads Tested

Unit	Parameter	Test Load	# of Units
Heat Boiler	NO_x, CO, VOC, PM* & Opacity	100% Load	1 Unit
	NO_x and PM*	50% Load	1 Unit

Sampling Personnel

Scott Chesnut, David Worgum, Danny Dizon, Thomas Franett, Carey Mott, Collin Wardell, Adam Manning, Mike Scullywest, Gary Dubrall and Richard Brennan with ETI performed the testing. Mr. Keith Craik with Shell coordinated the test program.

Even though the testing program was not for compliance purposes, the EPA was provided a test plan and notified of the testing at least 30 days in advance. No representative of the EPA was present during testing.

Other Important Background Information

The D utilizes a Clayton Heat Boiler rated at 7.97 million British Thermal Units of Heat Input per hour (MMBtu/hr). Testing on the D-22 Heat Boiler was conducted at the Keppel Shipyard facility in Singapore.

SUMMARY OF RESULTS

Units of Emission Measurements

The results of the D-22 air emissions tests are summarized in Section 2, Tables 2.0.1-2.1.2.

NO_x, CO and VOC test results are presented in concentration units of dry parts per million by volume (ppmdv), emission rate units of pounds per hour (lbs/hr) and emission factor units of pounds per gallon of fuel (lb/gal fuel) and pounds per million British Thermal Units of Heat Input (lbs/MMBtu). VOC was measured as total organic carbon (TOC) and reported as dry propane

PM test results are reported in concentration units of grams per dry standard cubic meter (g/dscm) and grains per dry standard cubic feet (grains/dscf), emission rate units of lb/hr and emission factor units of lb/gal fuel and lb/MMBtu.

Diluent O_2 and CO_2 test results are presented in units of dry percent by volume (%). Volumetric Flow Rate test results are presented in units of dry standard cubic meter per minute (dscm/m) and dry standard cubic feet per minute (dscf/m).

The D-22 was equipped with two fuel meters to measure fuel consumption and return to the day tank. The ship's operational data was electronically recorded at 5-minute intervals, throughout the source test. Printouts of the ship's operational data were provided and are included in Appendix E. Fuel data was the operational data collected.

Comments: Discussion of Quality Assurance and Errors

Quality assurance procedures listed in the above referenced test methods and referenced in the Quality Assurance Project Plan were performed and documented. The QA/QC procedures are described in the Method Description, Equipment, Sampling, Analysis and QA/QC sections of the report. Documentation of the QA/QC is provided in Appendix F.

The NO_x analyzer converter efficiency was confirmed to be within specifications in accordance with RM 7E Section 16.2 and can be found in Appendix F.

Laboratory analysis of the fuel used while running these tests showed the sulfur content to be less than the 15 ppm requirement for classification as ultra low sulfur diesel. The laboratory report for the fuel analysis can be found in Appendix B.

SOURCE OPERATION

Source and Process Description

The D-22 Heat Boiler is a Clayton model 200 rated at 7.97 MMBtu/hr.

Pollution Control Equipment

There is no pollution control equipment on this unit.

Flow Diagram

A drawing of the stack exhaust is contained in Appendix G.

Process and Control Operating Parameters During Testing

Average fuel consumption was recorded and provided to ETI and referenced in Table 6.0.2 and 6.1.2.

Operating Conditions

During the test program, the D-22 was operated as close as possible to 100% and 50% of the maximum intended operating load, based on fuel usage.

Shell has:

- The D-22 is equipped with 2 diesel fuel flow meters.
- The fuel flow meters are located as close as practical to the fuel intake of the boiler.
- The fuel flow meters are totalizing and non-resettable.

Testing or Process Interruptions and Changes

There were no interruptions or delays during the test program.

SAMPLING AND ANALYSIS PROCEDURES

Sample Port Location

Emissions from the D-22 outlet stack were sampled via two horizontally mounted ports located on the circular stack exit. The two sample ports are located 90 degrees apart.

The ports are located greater than 6 inside stack diameters downstream from the nearest flow disturbance and greater than 2 inside stack diameters upstream from the stack exit. The minimum number of sample points required is ten per port (20 total). The stack exit height is approximately 70 feet above the water line.

A diagram of the outlet stack is contained in Appendix G.

Point Description/Labeling – Ports/Stack

The stack's ports were not labeled, but were designated as left and right, as looking from the sample probe, for testing purposes. Particulate samples were collected from 20 sample points. Velocity traverses were performed at 20 sample points. Moisture tests were performed for 60 minutes.

A three-point gaseous stratification check was performed prior to testing. There was no stratification present in the exhaust gas stream; therefore a single point was used for the remainder of gas sampling.

Method Description, Equipment, Sampling, Analysis and QA/QC

Sampling and analytical procedures of the EPA Methods were followed as published in the "Quality Assurance Handbook for Air Pollution Measurement Systems" Volume III, US EPA 600/4-77-027b.

EPA Method 1 - Sample and Velocity Traverses for Stationary Sources

EPA Method 1 is 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 is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. A traverse point is 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 is determined from the gas density and from measurement of the average velocity head with a Type S (Stausscheibe 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 is extracted at a constant rate and then condensed and metered using an EPA Method 5 sample train. The weight gain of moisture condensed is determined gravimetrically by measuring the weight change of the impingers.

EPA Methods 3A, 7E and 10 – Determination of Gas Concentrations

The testing methodology for O_2, CO_2, NO_x and CO concentrations in the flue gas consist of a continuously operated gas analyzer system. Sample gases are first extracted from the stack through a heated probe/glass fiber filter assembly. A calibration gas purge valve is fitted ahead of the filter assembly for introducing calibration gases to the analyzer system. The samples are transported through Teflon sample lines to a portable unit containing the analyzers. Each of the samples is conditioned while a constant sample extraction rate is maintained. The analyzers detect the concentration of analyte gas within the sample and produce an electrical output signal proportional to analyte gas concentration. The electrical signal is recorded simultaneously on a digital DAS.

Instrument calibrations (zero and span checks) are performed per Method 7E. Sampling system calibrations and linearity determinations are 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 were constructed of 316 stainless steel, Viton O-rings, and a Teflon coated diaphragm.

Table 1.4

Parameter	Limits
Instrument Linearity	± 2% of calibration span
Instrument Bias	± 5% of calibration span
Calibration Gas	± 2% of calibration span
NO_x Converter Efficiency	≥ 90% of certified gas concentration
Instrument Zero Drift	± 3% of calibration span
Instrument Span Drift	± 3% of calibration span

EPA Method 5/202 - Determination of Particulate and Condensable Particulate Matter

Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature in the range of 248 ± 25°F (120 ± 14°C). The sample volume collected was at least 30 dscf per run. Particulate matter that is deposited on the nozzle, probe and front half of the filter holder is rinsed with acetone and collected in a sample bottle. The acetone is then evaporated off at the laboratory and desiccated for 24

hours. The particulate mass from the rinse and filter are determined gravimetrically after removal of uncombined water.

The condensable particulate matter (CPM), back half fraction, is the material that condenses after passing through the filter and is analyzed using Method 202. The method uses a Method 5 sampling train with the addition of a condenser, a water dropout impinger and a modified Greenburg Smith impinger (both dry) followed by a Teflon CPM filter. The potential artifacts from SO_2 are reduced using a condenser and dropout impinger to separate CPM from reactive gases. To improve the collection efficiency of CPM, an additional filter (the CPM filter) is placed between the second and third impingers. The impinger contents are immediately purged after the run for one hour with nitrogen to remove dissolved sulfur dioxide gases. The CPM filter is extracted with water and methylene chloride. The impingers are recovered, rinsed and the organic and aqueous fractions are separated using methylene chloride. The organic and aqueous fractions are then taken to dryness and residues weighed. The total of both fractions represents the CPM.

EPA Method 9 – Visual Determination of Opacity

This method involves the determination of plume opacity by qualified observers. The method includes procedures for the training and certification of observers and procedures to be used in the field for determination of plume opacity. The opacity of emissions from stationary sources is determined at the point of greatest opacity in that portion of the plume where water vapor is not present. The observer does not look at the plume continuously, but instead observes the plume momentarily at 15-second intervals. Opacity is determined as an average of 24 consecutive observations recorded at 15-second intervals. A set is composed of any 24 consecutive observations. Sets need not be consecutive in time and no two sets can overlap.

EPA Method 25A – Determination of VOC 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). The concentration is expressed in terms of propane (or other appropriate organic calibration gas) or in terms of carbon. The sampled gases were continuously extracted from the stack through a heated probe/filter assembly and a heated Teflon line to a mobile test trailer containing a flame ionization analyzer (FIA) gas analyzer. 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 strip chart recorder and DAS. A calibration error test was performed immediately prior to the test. Calibration drift tests were performed following each run or hourly if continuous sampling 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 or as carbon equivalents.

For the measurement of non-methane hydrocarbons (NMHC) an FIA with a methane cutter was used. The analyzer controls the flow of gas sample into the chromatographic column. As the sample was carried down the column, the various components moved at different speeds, as determined by their physical and chemical properties. Due to its low molecular weight and high volatility, methane moved faster than other organic compounds and was the first to emerge from the opposite end of the column. Upon leaving the column, the methane flowed back through a rotary valve and then to the flame ionization detector (FID). Once the methane peak was detected, the rotary valve returned to its original back-flush position. The NMHC's were back-flushed out and carried to the FID for measurement. Time required for analysis of one sample was about 70 seconds. Calibration was done using methane (2 ppm and up, balance nitrogen). The readout showed three values (methane, nonmethane and total) and held for 70 seconds.

Nomenclature

A_d = cross-sectional area of stack, m^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

ΔH = differential orifice meter pressure, mm H_2O or inches H_2O

ΔP = stack gas velocity pressure, mmH_2O or inches H_2O

$\sqrt{\Delta P}_{avg}$ = average of square roots of ΔP, $\sqrt{\text{mm } H_2O}$, $\sqrt{\text{inches } H_2O}$

D_s = diameter of stack, ft^2

F_{Btu} = fuel heating value, gross Btu/lb or gross Btu/gal

F_{den} = fuel density, kg/liter or lb/gal

F_{grv} = fuel API specific gravity

F_{O2} = F factor for dry effluent, used with percent O_2, dscf/MMBtu

I = percent isokinetic sampling rate

K_p = pitot tube constant = 34.97 m/sec $\sqrt{\frac{(\text{g / g – mole})(\text{mm Hg})}{(^{o}\text{K})(\text{mm } H_2O)}}$

K_5 = isokinetic rate constant, 4.32 for metric units; 0.0945 for English units

M_b = mass of field train total cpm blank, g

M_c = mass of NH_4^+ added to sample to form ammonium sulfate, g

M_{cpm} = mass of condensable particulate matter

M_d = molecular weight of stack gas, dry basis, g/g-mole

M_i = mass of inorganic cpm, g

M_o = mass of organic cpm, g

M_w = molecular weight of stack gas, wet basis, g/g-mole, $M_d (1- B_{ws}) + 18(B_{ws})$

N = normality of ammonium hydroxide titrant

$\%CO_2$ = percent by volume of carbon dioxide in stack gas

$\%N_2$ = percent by volume of nitrogen in stack gas

$\%O_2$ = percent by volume of oxygen in stack gas

P_{bar} = barometric pressure, mm Hg or inches Hg

P_s = absolute stack gas pressure, mm Hg or inches Hg

P_{static} = static pressure of the stack, mm Hg or inches H_2O

P_{std} = standard absolute pressure, 29.92 inches Hg or 760 mm Hg

Q_f = fuel flow rate, liter/hr or gal/hr

Q_{std} = stack flow rate, dscm/m or dscf/min

θ = sample time, minutes

T_m = meter temperature, ^{o}C or ^{o}F

T_s = average stack temperature, ^{o}C or ^{o}F

T_{std} = standard absolute temperature, $528^{o}R$ or $293^{o}K$

$T_{s(avg)}$ = Average absolute stack temperature, $^{o}K = 273 + T_s$ (^{o}F)

V_{lc} = weight of water gain in the impingers, g

V_{mstd} = corrected meter volume, dscm

V_S = average stack gas velocity, m/sec.

V_t = volume of NH_4OH titrant, ml

Y = dry gas meter calibration factor

SUMMARIES

100% LOAD

50% LOAD

Summary Gases

Client	Shell	**Date:**	10/05/10
City:	Singapore, Singapore	**Boiler Make:**	Clayton
ETI Job No:	10-1822	**Boiler Model:**	200
Site:	Discoverer	**Boiler Serial Number:**	-
Unit:	D-22	**Load:**	100%

Table 2.0.1

Start Time:	**11:18**	**12:36**	**14:17**	
End Time:	**12:17**	**13:35**	**15:16**	
Fuel Data	**Run Number**			**Average**
	1	**2**	**3**	
gal/hr	54.9	54.9	54.9	**54.9**
MMBtu/hr	7.5	7.5	7.5	**7.5**
Stack Parameters	**Run Number**			**Average**
	1	**2**	**3**	
% Moisture	11.5	11.5	11.7	**11.6**
M-1-4 Q_{std}, scfm	1476.0	1436.0	1393.0	**1435**
O_2	**Run Number**			**Average**
	1	**2**	**3**	
Percent	4.8	4.9	5.4	**5.0**
CO_2	**Run Number**			**Average**
	1	**2**	**3**	
Percent	11.4	11.3	11.0	**11.2**
NO_x	**Run Number**			**Average**
	1	**2**	**3**	
ppmdv	89.2	89.1	80.6	**86.3**
lbs/hr	0.942	0.915	0.803	**0.887**
lb/gal fuel	0.0172	0.0167	0.0146	**0.0162**
lb/MMBtu	0.126	0.122	0.107	**0.118**
CO	**Run Number:**			
	1	**2**	**3**	**Average**
ppmdv	58.5	55.5	53.8	**55.9**
lb/hr	0.376	0.347	0.326	**0.350**
lb/gal fuel	0.00685	0.00632	0.00594	**0.00637**
lb/MMBtu	0.0501	0.0463	0.0435	**0.0466**
VOC	**Run Number:**			
	1	**2**	**3**	**Average**
ppmwv	0.95	1.23	0.04	**0.74**
ppmdv	1.07	1.39	0.05	**0.84**
lb/hr	0.0108	0.0137	0.0005	**0.0083**
lb/gal fuel	0.000197	0.000250	0.000009	**0.000152**
lb/MMBtu	0.00144	0.00183	0.00007	**0.00111**

D-21 & 22 NO_x: 0.20 lbs/MMBtu; CO: 0.0770 lbs/MMBtu; VOC: 0.00140 lb/MMBtu