Consumers Energy

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Compliance Test Report

EUENGINE3-1, 3-2, 3-3, 3-4 & 3-5

Ray Compressor Station
69333 Omo Road
Armada, Michigan 48005
State Registration Number (SRN) B6636

Test Dates: August 11 - 13, 2015

Report Submitted:
October 9, 2015

RECEIVED
OCT 12 2015
AIR QUALITY DIV.

Work Order No. 24148567
Report Revision 0

Test Performed by the Consumers Energy Company
Regulatory Compliance Testing Section
Laboratory Services Department

1.0 INTRODUCTION

Identification, location and dates of tests

On August 11-13, 2015, Consumers Energy Company's (CEC) Regulatory Compliance Testing Section (RCTS) performed air emission testing on five (5) 4-stroke lean burn (4SLB) natural gas-fired, reciprocating internal combustion engines (RICE) identified as EUENGINE31, EUENGINE32, EUENGINE33, EUENGINE34, EUENGINE35 (i.e., production engines) installed and operating at CEC's Ray Compressor Station in Armada, Michigan.

Please note this document follows the Michigan Department of Environmental Quality (MDEQ) format described in the December, 2013, *Format for Submittal of Source Emission Test Plans and Reports* and reproducing only a portion may omit critical substantiating documentation or cause information to be taken out of context. If any portion of this report is reproduced, please exercise due care in this regard.

Purpose of testing

This test event was performed to evaluate compliance with (a) the RICE National Emission Standards for Hazardous Air Pollutants (NESHAP) in 40 CFR Part 63, Subpart ZZZZ, and (b) the Standards of Performance for Stationary Spark Ignition (SI) Internal Combustion Engines (ICE) in 40 CFR Part 60, Subpart JJJJ, as outlined in the facility Renewable Operating Permit (ROP) No. MI-ROP-B6636-2015. A summary of specific test parameters is shown in Table 1:

TABLE 1

Summary of 40 CFR 63, Subpart ZZZZ and 40 CFR 60, Subpart JJJJ Test Parameters

Test Parameter	Measurement Unit	Test Location(s)	Regulation
Carbon Monoxide (CO) Efficiency	Ppmvd (part per million by volume, dry basis), corrected to 15% Oxygen (O_2)	Pre and Post Oxidation Catalyst	Subpart ZZZZ
Nitrogen Oxides (NO_x), CO[1] & Non-Methane Volatile Organic Compounds (VOC as NMOC)	grams per horsepower hour (g/HP-hr)	Post Oxidation Catalyst (Engine Exhaust)	Subpart JJJJ

[1] Please note that 40 CFR Part 60, Subpart JJJJ, Table 1, footnote (b), indicates RICE units such as the Ray Compressor RICE in this report which successfully meet the CO requirements of 40 CFR Part 63, Subpart ZZZZ, are not subject to the 40 CFR Part 60, Subpart JJJJ CO standards. However, to facilitate report formatting the measured RICE CO parameters in this report shall be presented hereafter in conjunction with Subpart JJJJ NO_x and VOC as NMOC parameters.

Brief description of source

The Ray Compressor Station operates Caterpillar Model 3616 4SLB engines for the purpose of maintaining natural gas pipeline system and storage reservoir pressure. Each engine fires pipeline quality natural gas exclusively and is equipped with modular oxidation catalysts designed to reduce CO and VOC emissions.

Names, addresses, and telephone numbers of the contacts for information regarding the test and the test report, and names and affiliation of all personnel involved in conducting the testing

A Test Protocol dated May 18, 2015 was submitted and subsequently approved by the MDEQ in their letter dated July 2, 2015. The RICE test program was conducted August 11 - 13, 2015 by CEC RCTS employees Joe Mason and Gregg Koteskey. Mr. Dominic Tomasino, CEC Gas O&M Senior Field Leader, coordinated the test along with CEC Corporate Environmental Senior Engineer Ms. Amy Kapuga, whom also coordinated the collection of RICE operating data. MDEQ representative Mr. Thomas Maza was onsite to witness a portion of the testing. Table 2 contains test program participant contact information.

TABLE 2

Ray Compressor Station RICE Test Program Participants

Responsible Party	Address	Contact
Test Facility	Ray Compressor Station 69333 Omo Road Armada, Michigan 48005	Mr. Dominic Tomasino 586-784-2096 dominic.tomasino@cmsenergy.com
Corporate Air Quality Contact	Consumers Energy Company Environmental Services Department 1945 West Parnall Road Jackson, Michigan 49201	Ms. Amy Kapuga 517-788-2201 amy.kapuga@cmsenergy.com
Test Representative	Consumers Energy Company Regulatory Compliance Testing Section 17010 Croswell Street West Olive, Michigan 49460	Mr. Joe Mason, QSTI 231-720-4856 joe.mason@cmsenergy.com
State Representative	Michigan Department of Environmental Quality Technical Programs Unit 525 W. Allegan, Constitution Hall Lansing, Michigan 48909	Mr. Thomas Maza MDEQ-AQD Detroit Field Office 313-456-4709 mazat@michigan.gov

2.0 SUMMARY OF RESULTS

Operating Data

RICE operating data collected throughout each run included catalyst inlet temperature, catalyst pressure drop, engine load, ambient temperature, barometric pressure, fuel flow rate, suction pressure, discharge pressure and horsepower. Engine horsepower was used to verify engine load during the performance test, as Subpart ZZZZ § 63.6620(b) states *the test must be conducted at any load condition within plus or minus 10 percent of 100 percent load.*

Applicable Permit Number

Ray Compressor Station operates pursuant to the terms and conditions of ROP No. MI-ROP-B6636-2015.

Results

The dry basis CO, NO_x and VOC as NMOC concentrations and emissions summarized in Tables 2 and 3 indicate each production engine meets the applicable RICE regulatory limits in 40 CFR Part 63, Subpart ZZZZ, and 40 CFR Part 60, Subpart JJJJ.

TABLE 3
Summary of 40 CFR 63 Subpart ZZZZ Results

Source	CO Reduction Efficiency (%) [ZZZZ Limit = ≥93%]	Catalyst Inlet Temperature (°F) [ZZZZ Limit = ≥450°F and ≤ 1350°F]	Catalyst Pressure Drop (Inches Water Gauge) [ZZZZ Limit = ±2" from Initial Test]	Initial Catalyst Pressure Drop (Inches Water Gauge)
EUENGINE31	99.7	835	2.1	2.0
EUENGINE32	99.7	863	2.6	2.3
EUENGINE33	99.6	849	2.2	2.1
EUENGINE34	99.6	850	2.7	2.4
EUENGINE35	99.6	825	2.4	2.1

The preceding dry basis CO concentrations, corrected to 15% O_2 as measured before and after the oxidation catalysts, indicate that each engine meets the 40 CFR Part 63, Subpart ZZZZ, minimum CO percent efficiency requirement of 93 percent. The associated oxidation catalyst on each engine also meets the operating requirements for catalyst inlet temperature and catalyst pressure drop.

TABLE 4

Summary of 40 CFR 60 Subpart JJJJ Results

Test Parameter	EUENGINE 31	EUENGINE 32	EUENGINE 33	EUENGINE 34	EUENGINE 35	ROP/JJJJ Limit g/HP-hr
NOx, g/HP-hr	0.3	0.3	0.4	0.3	0.3	0.5/2.0
CO, g/HP-hr	0.006	0.006	0.007	0.007	0.006	0.2/4.0
VOC, (as NMOC), g/HP-hr	0.03	0.003	0.02	0.002	0.005	0.19/1.0

The preceding NO_x, CO and VOC RICE exhaust g/HP-hr emission rates meet the ROP and 40 CFR Part 60, Subpart JJJJ emission limits.

3.0 SOURCE DESCRIPTION

Description of Process

The Ray Compressor Station is a natural gas compressor station. The purpose of the facility is to maintain pressure of natural gas in order to move it in and out of storage reservoirs and along the pipeline system. The five RICE driven compressor units were installed in 2013 to maintain station reliability, working in conjunction with other RICE at the facility.

NO_x emissions from each engine are minimized through the use of lean-burn combustion technology. Lean-burn combustion refers to a high level of excess air (generally 50% to 100% relative to the stoichiometric amount) in the combustion chamber. The excess air absorbs heat during the combustion process, thereby reducing the combustion temperature and pressure and resulting in lower NO_x emissions.

CO and VOC emissions from each engine are controlled by modular oxidation catalysts manufactured from proprietary materials which effectively reduce CO and volatile organic compound oxidation temperatures to that produced from RICE engine exhaust ducts. The catalyst vendor guarantees a CO reduction efficiency of 93% and estimates formaldehyde and non-methane, non-ethane hydrocarbon (NMNEHC) efficiencies of 85% and 75%, respectively.

Process Flow Sheet or Diagram

NA

Type and Quantity of Raw Material Processed During the Tests

NA

Maximum and Normal Rated Capacity of the Process

Each Caterpillar Model 3616 4SLB RICE production engine at Ray Compressor Station has a rated heat input of 32 million British thermal unit (mmBtu) per hour and a rated output of 4,735 horsepower. Table 5 contains pertinent vendor provided engine specifications.

TABLE 5

Summary of RICE Specifications [1], EUENGINE3-1-EUENGINE3-5

Make	Caterpillar
Model	G3616
Output (brake-horsepower)	4,735
Heat Input, LHV (mmBtu/hour)	32.0
Exhaust Gas Temp. (°F)	856

[1] Vendor supplied engine specifications are based upon 100% of rated engine capacity.

Description of Process Instrumentation Monitored During the Test

RICE operating data collected throughout each run included catalyst inlet temperature, pressure drop across catalyst, engine load, ambient temperature, barometric pressure, fuel flow rate, suction pressure, discharge pressure and horsepower. Engine horsepower was used to verify engine load during the performance test, as Subpart ZZZZ § 63.6620 (b) states *the test must be conducted at any load condition within plus or minus 10 percent of 100 percent load.*

4.0 SAMPLING AND ANALYTICAL PROCEDURES

Description of sampling train(s) and field procedures

Triplicate one-hour runs were conducted at the engine oxidation catalyst inlet for CO, O_2 and CO_2 simultaneously with measurements of NO_x, CO, VOC, O_2 and CO_2 at the engine (oxidation catalyst) exhaust. CO efficiency calculations were determined using specifications in 40 CFR Part 63, Subpart ZZZZ §63.6620 Equation 1 and Table 4, and NO_x, CO and VOC emission rates were based on Equations 1-3 and Table 2 in 40 CFR Part 60, Subpart JJJJ §60.4244.

There were no deviations in the testing, sampling, analytical, and calibration procedures outlined in the facility test protocol dated May 18th, 2015. Please note that O_2 was the diluent gas used to correct CO concentrations to 15% O_2 when determining percent CO reduction. CO_2 was measured as well since Subpart ZZZZ allows for CO_2 correction factors based on O_2 to CO_2 fuel factor ratios described in §63.6620 (e)(2)(ii)(Eq.3). In the event O_2 diluent measurements were not possible, CO concentrations could be corrected to 15% O_2 based on dry basis CO_2 concentrations as described in Equation 4, § 63.6620 (e)(2)(iii), utilizing CO_2 correction factors derived from F_c and F_d fuel factors obtained from natural gas fuel sample analyses.

All components of the CO_2, O_2, NO_x, CO and VOC extractive sample systems in contact with flue gas were constructed of Type 316 stainless steel and/or Teflon. The CO_2, O_2, NO_x, and CO analyzers were calibrated with U.S. EPA Protocol calibration gases at a minimum of three points: low (0-20% of calibration span), mid-level (40-60% of calibration span) and high-level gas (equal to the calibration span) following specifications in U.S. EPA Method 7E. The VOC instrument was calibrated with four propane in nitrogen gases following U.S. EPA Method 25A specifications at the zero level, low (25 to 35 percent of calibration span), mid (45 to 55 percent of calibration span and high (equivalent to instrument span). All instruments were operated thereafter to insure that zero drift, calibration gas drift, bias and calibration error met the specified method requirements. The output signal from each analyzer was connected to a computerized data acquisition system (DAS). The extractive sample system apparatus diagram is shown in Figure 1.

The CO_2, O_2, NO_x and CO engine exhaust gases were conveyed via a heated sample line to an ice/water bath to remove moisture from the gas prior to analyzer injections. A slipstream of the wet sample was diverted and injected into the VOC instrument prior to the ice/water bath as VOC concentrations are measured on a ppmv, wet basis.

After correcting the post-test analyzer data for drift and bias, average pollutant concentrations at the catalyst inlet and outlet were corrected to 15 percent O_2. The percent CO efficiency was then calculated, followed by the NOx and VOC emission rates on a g/HP-hr dry basis. CO_2 and O_2, concentrations were measured as percent by volume, dry basis.

4.1 Traverse Points

Due to the proprietary nature and design of the abatement equipment, the catalyst EUENGINE3-1 through 3-5 inlet sampling locations are a-typical relative to U.S. EPA Method 1 *"Sample and Velocity Traverses for Stationary Sources"* criteria. Gaseous concentrations were obtained from one sample point prior to the catalyst inlet while three sample points located based on Method 7E requirements were traversed at the engine exhaust. Figure 2 of this report illustrates the path of engine effluent as it enters and exits the oxidation catalyst.

4.2 Diluent/Molecular Weight

CO_2 and O_2 concentrations were measured at the catalyst inlet and outlet using a non-dispersive infrared (NDIR) analyzer equipped with paramagnetic O_2 analysis capacity, following the guidelines of U.S. EPA Method 3A, *Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from a Stationary Source (Instrumental Analyzer Procedure).*

4.3 Moisture Content

The catalyst exhaust gas moisture content was measured using U.S. EPA Reference Method 4, *Determination of Moisture in Stack Gases* in conjunction with each Subpart JJJJ test. Effluent gas was drawn through a series of four impingers; the first two of which contained water, the third was empty and the fourth contained indicating silica gel. The impingers were immersed in an ice bath during each test to achieve efficient moisture condensation, and collected water vapor was determined gravimetrically for calculating exhaust gas percent moisture.

4.4 Nitrogen Oxides

NO_x concentrations were measured at the engine exhaust using a chemiluminescent analyzer following the guidelines of U.S. EPA Method 7E, *Determination of Nitrogen Oxides from Stationary Sources (Instrumental Analyzer Procedure).*

4.5 Carbon Monoxide

CO concentrations were measured at the catalyst inlet and outlet using a gas filter correlation (GFC) analyzer following the guidelines of U.S. EPA Reference Method 10, *Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure).*

4.6 Volatile Organic Compounds

VOC concentrations were monitored at the engine exhaust using a Thermo Model 55i Direct Methane and Non-methane Analyzer following the guidelines of U.S. EPA Method 25A, *Determination of Total Gaseous Organic Concentration Using a Flame ionization Analyzer (FIA).* The flame ionization detector (FID) analytical principal is employed to determine the total hydrocarbon concentration and a gas chromatographic column is used to separate methane from other organic compounds.

The instrument injects sample gas into the column, and due to methane's low molecular weight and high volatility, the compound moves through the column more quickly than other existing organic compounds and exits the column to be analyzed in the FID. The column is then flushed with inert carrier gas and the remaining non-methane organic compounds are analyzed in the FID. This analytical technique allows separate measurements for methane and non-methane organic compounds via the use of a single FID.

Quality Assurance Procedures

Each U.S. EPA reference method performed during this test contains specific language stating that to obtain reliable results, persons using these methods should have a thorough knowledge of the techniques associated with each method. To that end, CEC RCTS attempts to minimize any factors which could cause sampling errors by implementing a quality assurance (QA) program into every component of field testing, including the following information.

U.S. EPA Protocol gas standards certified according to the U.S. EPA Traceability Protocol for Assay & Certification of Gaseous Calibration Standards; Procedure G-1; September, 1997 or May, 2012 version and certified to have a total relative uncertainty of ±1 percent were used to calibrate the analyzers during the test program. Although not required in the context of this Parts 60 and 63 test program, the vendors providing the calibration gases also participate in the Protocol Gas Verification Program (PGVP), an EPA audited program recently developed for 40 CFR Part 75.

The extractive sample system instruments were calibrated and operated following the appropriate method guidelines, based on specifications contained in Method 7E (as referenced in Methods 3A and 10). Before daily testing began, an analyzer calibration error (ACE) test was conducted by introducing the calibration gases directly into each analyzer. If the measured response was greater than ±2 percent of instrument span (or greater than 0.5 ppmv absolute difference), corrective action was taken followed by another ACE. Thereafter, an initial system bias check was conducted by injecting low and upscale calibration gases consecutively into the sampling system at the probe outlet which emulates the manner in which an exhaust gas sample is collected. The sample system response time to the calibration gas is documented and the sample system bias requirement of ≤ 5.0 percent of instrument span is verified. If the bias criteria are not met, additional corrective action is taken to do so. After completing these QA requirements, the first run began after waiting twice the system response time. After each run was completed, low and upscale bias calibrations were performed to again quantify sample system drift and bias before waiting twice the system response time to start the next run.

Description of recovery and analytical procedures
NA

Dimensioned sketch showing all sampling ports and a sketch of cross-sectional view of stack indicating traverse point locations and exact stack dimensions
The exhaust stack configuration for the Caterpillar Model G3616 engines (i.e., EUENGINE3-1, EUENGINE3-2, EUENGINE3-3, EUENGINE3-4 and EUENGINE3-5) is shown in Figure 2, including hand markups which are intended to provide an illustration of the flue gas path through the stack.

5.0 TEST RESULTS AND DISCUSSION

Detailed tabulation of results, including process operating conditions and flue gas conditions

Except as noted, Tables within this report contain a summary of percent CO reduction and NO_x, CO and VOC emission rates from each RICE. RICE operating data, calculation spreadsheets, field data sheets, calibration information, fuel analyses and analytical data are contained in Attachments 1 - 6.

Discussion of significance of results relative to operating parameters and emission regulations

40 CFR 63 Subpart ZZZZ

The measured CO percent reduction met the 93 percent reduction efficiency requirement and is therefore considered compliant with 40 CFR 63, Subpart ZZZZ. Furthermore, catalyst inlet temperatures and pressure drop monitored throughout testing was shown to be within the required ranges.

40 CFR 60 Subpart JJJJ

The NO_x, CO and VOC emission rates are within the ROP and 40 CFR 60 Subpart JJJJ emission limits for each production engine.

Discussion of any variations from normal sampling procedures or operating conditions, which could have affected the results

While not required by Method 25A, the VOC data was adjusted for analyzer drift using U.S. EPA Method 7E, *Determination of Nitrogen Oxides from Stationary Sources (Instrumental Analyzer Procedure* specifications. This adjustment was not specifically requested by the MDEQ in their protocol approval letter response; however this presentation is consistent with previous MDEQ Method 25A data requests. For the purposes of this test program, RCTS did not quality assure the methane channel on the Thermo Model 55i analyzer.

Documentation of any process or control equipment upset condition which occurred during the testing

NA

Description of any major maintenance performed on the air pollution control device(s) during the three month period prior to testing

NA

In the event of a re-test, a description of any changes made to the process or air pollution control device(s)

NA

Results of any quality assurance audit sample analyses required by the reference method
NA

Calibration sheets for the dry gas meter, orifice meter, pitot tube, and any other equipment or analytical procedures which require calibration
Attachment 4 contains the analyzer calibration data, response time test results, NO_2 to NO converter efficiency check and calibration gas Certificates of Analysis.

Sample calculations of all the formulas used to calculate the results
Sample calculations for all formulas used in the test report are contained in Attachment 6.

Copies of all field data sheets, including any pre-testing, aborted tests, and/or repeat attempts
Please refer to Attachment 1 for process data collected during the test runs; Attachment 2 for calculation spreadsheets for each of the test runs; and Attachment 3 for data sheets with the measured concentrations for each test run.

Copies of all laboratory data including QA/QC
For this testing event, laboratory data includes the results of the natural gas fuel analyses which are presented in Attachment 5.

TABLE 6
RAY COMPRESSOR STATION
SUMMARY OF RICE EFFICIENCY AND EMISSIONS, EUENGINE3-1
August 13, 2015

Time Period	Run 1	Run 2	Run 3	Average
	0852-0952	1011-1111	1133-1233	
Engine Process Conditions				
Engine Speed, Revolutions Per Minute:	928.8	928.1	929.0	**928.6**
Brake Horsepower:	4,386	4,383	4,381	**4,383**
Load, Percent:	99.6	99.7	99.6	**99.6**
Fuel Flow, SCFM	522.8	523.7	525.3	**523.9**
Suction Pressure, PSIG	593.8	591.7	590.0	**591.8**
Catalyst Delta P, Inches of Water:	2.1	2.1	2.1	**2.1**
Catalyst Inlet Temperature, degrees F:	834.8	834.5	835.8	**835.0**
Catalyst Inlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (Percent):	12.0	11.9	11.9	**11.9**
Drift Corrected CO Concentration, Dry (ppmvd):	429.8	429.7	427.0	**428.9**
Corrected CO Concentration (ppmvd @ 15% O2):	285.2	282.9	280.8	**283.0**
Catalyst Outlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (percent):	11.9	11.9	11.9	**11.9**
Drift Corrected CO Concentration, Dry (ppmvd):	1.3	1.4	1.4	**1.3**
Corrected CO Concentration (ppmvd @ 15% O2):	0.9	0.9	0.9	**0.88**
CO Reduction Efficiency (≥93%, 40 CFR Part 63, Subpart ZZZZ):	99.7	99.7	99.7	**99.7**
Emission Rate, Grams Per Brake Horsepower:	0.006	0.006	0.006	**0.006**
ROP Emission Limit, Grams Per Brake Horsepower[1]:	0.2	0.2	0.2	**0.2**
Drift Corrected Nitrogen Oxides Concentration (ppmvd):	41.7	42.0	42.8	**42.2**
Emission Rate, Grams Per Brake Horsepower:	0.3	0.3	0.3	**0.3**
PTI Emission Limit, Grams Per Brake Horsepower:	0.5	0.5	0.5	**0.5**
Volatile Organic Compounds (as NMOC) Concentration, Dry (ppmvd), Expressed as Propane:	0.52	10.13	2.73	**4.5**
VOC (as NMOC) Emission Rate, Grams Per Brake Horsepower:	0.004	0.08	0.02	**0.03**
PTI Emission Limit, Grams Per Brake Horsepower Hour[1]:	0.19	0.19	0.19	**0.19**

[1] The PTI CO, NO_x and VOC emission limits are more stringent than the applicable limits in 40 CFR Part 60, Subpart JJJJ, which are as follows: CO = 4.0 grams/HP-hr; NO_x = 2.0 grams/HP-hr; VOC = 1.0 grams/HP-hr

TABLE 7
RAY COMPRESSOR
SUMMARY OF RICE EFFICIENCY AND EMISSIONS, EUENGINE3-2
August 12, 2015

Time Period	Run 1	Run 2	Run 3	Averages
	1321-1421	1438-1538	1558-1658	
Engine Process Conditions				
Engine Speed, Revolutions Per Minute:	967.6	966.8	967.0	**967.1**
Brake Horsepower:	4,524	4,518	4,525	**4,522**
Load, Percent:	98.8	98.7	99	**98.7**
Fuel Flow, SCFM	553.6	554.11	554.5	**554.1**
Suction Pressure, PSIG	586.0	588.0	590	**587.8**
Catalyst Delta P, Inches of Water:	2.6	2.6	2.6	**2.6**
Catalyst Inlet Temperature, degrees F:	862.9	863.0	862.1	**862.7**
Catalyst Inlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (Percent):	11.8	11.8	11.7	**11.7**
Drift Corrected CO Concentration, Dry (ppmvd):	385.9	385.0	383.5	**384.8**
Corrected CO Concentration (ppmvd @ 15% O2):	249.5	248.7	246.5	**248.2**
Catalyst Outlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (percent):	11.7	11.7	11.7	**11.7**
Drift Corrected CO Concentration, Dry (ppmvd):	1.3	1.3	1.4	**1.3**
Corrected CO Concentration (ppmvd @ 15% O2):	0.8	0.8	0.9	**0.8**
CO Reduction Efficiency (≥93%, 40 CFR Part 63, Subpart ZZZZ):	99.7	99.7	99.7	**99.7**
Emission Rate, Grams Per Brake Horsepower:	0.006	0.006	0.006	**0.006**
ROP Emission Limit, Grams Per Brake Horsepower[1]:	0.2	0.2	0.2	**0.2**
Drift Corrected Nitrogen Oxides Concentration (ppmvd):	42.9	43.3	43.74	**43.3**
Emission Rate, Grams Per Brake Horsepower:	0.3	0.3	0.3	**0.3**
PTI Emission Limit, Grams Per Brake Horsepower:	0.5	0.5	0.5	**0.5**
Volatile Organic Compounds (as NMOC) Concentration, Dry (ppmvd), Expressed as Propane:	0.26	0.43	0.61	**0.43**
VOC (as NMOC) Emission Rate, Grams Per Brake Horsepower:	0.002	0.003	0.005	**0.003**
PTI Emission Limit, Grams Per Brake Horsepower Hour[1]:	0.19	0.19	0.19	**0.19**

[1] The PTI CO, NO_x and VOC emission limits are more stringent than the applicable limits in 40 CFR Part 60, Subpart JJJJ, which are as follows: CO = 4.0 grams/HP-hr; NO_x = 2.0 grams/HP-hr; VOC = 1.0 grams/HP-hr

TABLE 8
RAY COMPRESSOR
SUMMARY OF RICE EFFICIENCY AND EMISSIONS, EUENGINE3-3
August 12, 2015

Time Period	Run 1	Run 2	Run 3	Averages
	0900-1000	1022-1122	1144-1244	
Engine Process Conditions				
Engine Speed, Revolutions Per Minute:	933	933	930	**932**
Brake Horsepower:	4,456	4452	4450	**4453**
Load, Percent:	101	101	101	**101**
Fuel Flow, SCFM	538.9	539.7	540.5	**539.7**
Suction Pressure, PSIG	578	581	583	**580.6**
Catalyst Delta P, Inches of Water:	2.2	2.2	2.2	**2.2**
Catalyst Inlet Temperature, degrees F:	850	850	847	**849**
Catalyst Inlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (Percent):	11.6	11.7	11.9	**11.8**
Drift Corrected CO Concentration, Dry (ppmvd):	380.2	375.7	374.1	**376.7**
Corrected CO Concentration (ppmvd @ 15% O2):	242.3	241.6	244.8	**242.9**
Catalyst Outlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (percent):	11.6	11.6	11.7	**11.6**
Drift Corrected CO Concentration, Dry (ppmvd):	1.6	1.5	1.4	**1.5**
Corrected CO Concentration (ppmvd @ 15% O2):	1.0	1.0	0.9	**1.0**
CO Reduction Efficiency (≥93%, 40 CFR Part 63, Subpart ZZZZ):	99.6	99.6	99.6	**99.6**
Emission Rate, Grams Per Brake Horsepower:	0.007	0.007	0.006	**0.007**
ROP Emission Limit, Grams Per Brake Horsepower[1]:	0.2	0.2	0.2	**0.2**
Drift Corrected Nitrogen Oxides Concentration (ppmvd):	47.7	47.2	47.0	**47.3**
Emission Rate, Grams Per Brake Horsepower:	0.4	0.4	0.4	**0.4**
PTI Emission Limit, Grams Per Brake Horsepower:	0.5	0.5	0.5	**0.5**
Volatile Organic Compounds (as NMOC) Concentration, Dry (ppmvd), Expressed as Propane:	3.29	4.56	0.37	**2.74**
VOC (as NMOC) Emission Rate, Grams Per Brake Horsepower:	0.02	0.03	0.003	**0.02**
PTI Emission Limit, Grams Per Brake Horsepower Hour[1]:	0.19	0.19	0.19	**0.19**

[1] The PTI CO, NO_x and VOC emission limits are more stringent than the applicable limits in 40 CFR Part 60, Subpart JJJJ, which are as follows: CO = 4.0 grams/HP-hr; NO_x = 2.0 grams/HP-hr; VOC = 1.0 grams/HP-hr

TABLE 9

RAY COMPRESSOR
SUMMARY OF RICE EFFICIENCY AND EMISSIONS, EUENGINE3-4
August 11, 2015

Time Period	Run 1	Run 2	Run 3	Averages
	1334-1434	1457-1557	1615-1715	
Engine Process Conditions				
Engine Speed, Revolutions Per Minute:	959.7	960.0	943.76	**954.5**
Brake Horsepower:	4,522	4,522	4,521	**4522**
Load, Percent:	99.6	99.5	101.3	**100.1**
Fuel Flow, SCFM	535.50	535.7	536.3	**535.8**
Suction Pressure, PSIG	597.1	593.0	577.4	**589.2**
Catalyst Delta P, Inches of Water:	2.7	2.7	2.7	**2.7**
Catalyst Inlet Temperature, degrees F:	850.9	850.6	848.6	**850.0**
Catalyst Inlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (Percent):	11.9	11.9	11.9	**11.9**
Drift Corrected CO Concentration, Dry (ppmvd):	391.0	391.7	390.1	**390.9**
Corrected CO Concentration (ppmvd @ 15% O2):	255.1	255.9	254.8	**255.3**
Catalyst Outlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (percent):	11.8	11.9	11.8	**11.8**
Drift Corrected CO Concentration, Dry (ppmvd):	1.4	1.5	1.6	**1.5**
Corrected CO Concentration (ppmvd @ 15% O2):	0.9	1.0	1.1	**1.0**
CO Reduction Efficiency (≥93%, 40 CFR Part 63, Subpart ZZZZ):	99.6	99.6	99.6	**99.6**
Emission Rate, Grams Per Brake Horsepower:	0.007	0.007	0.008	**0.007**
ROP Emission Limit, Grams Per Brake Horsepower[1]:	0.2	0.2	0.2	**0.2**
Drift Corrected Nitrogen Oxides Concentration (ppmvd):	43.8	42.8	43.4	**43.3**
Emission Rate, Grams Per Brake Horsepower:	0.3	0.3	0.3	**0.3**
PTI Emission Limit, Grams Per Brake Horsepower:	0.5	0.5	0.5	**0.5**
Volatile Organic Compounds (as NMOC) Concentration, Dry (ppmvd), Expressed as Propane:	0.17	0.26	0.23	**0.22**
VOC (as NMOC) Emission Rate, Grams Per Brake Horsepower:	0.001	0.002	0.002	**0.002**
PTI Emission Limit, Grams Per Brake Horsepower Hour[1]:	0.19	0.19	0.19	**0.19**

[1] The PTI CO, NO_x and VOC emission limits are more stringent than the applicable limits in 40 CFR Part 60, Subpart JJJJ, which are as follows: CO = 4.0 grams/HP-hr; NO_x = 2.0 grams/HP-hr; VOC = 1.0 grams/HP-hr

TABLE 10
RAY COMPRESSOR
SUMMARY OF RICE EFFICIENCY AND EMISSIONS, EUENGINE3-5
August 11, 2015

Time Period	Run 1 0905-1005	Run 2 1031-1131	Run 3 1156-1256	Averages
Engine Process Conditions				
Engine Speed, Revolutions Per Minute:	960.1	959.4	959.7	**959.7**
Brake Horsepower:	4,520	4,523	4,521	**4,521**
Load, Percent:	99.4	99.5	99.5	**99.4**
Fuel Flow, SCFM	528.6	526.7	525.8	**527.0**
Suction Pressure, PSIG	587.7	600.0	602.2	**596.6**
Catalyst Delta P, Inches of Water:	2.4	2.4	2.4	**2.4**
Catalyst Inlet Temperature, degrees F:	826.7	825.4	824.2	**825.4**
Catalyst Inlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (Percent):	12.1	12.2	12.1	**12.2**
Drift Corrected CO Concentration, Dry (ppmvd):	466.6	454.3	447.3	**456.1**
Corrected CO Concentration (ppmvd @ 15% O2):	311.2	307.2	300.4	**306.3**
Catalyst Outlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (percent):	11.9	12.0	12.0	**12.0**
Drift Corrected CO Concentration, Dry (ppmvd):	2.0	1.8	1.6	**1.8**
Corrected CO Concentration (ppmvd @ 15% O2):	1.3	1.2	1.1	**1.2**
CO Reduction Efficiency (≥93%, 40 CFR Part 63, Subpart ZZZZ):	99.6	99.6	99.6	**99.6**
Emission Rate, Grams Per Brake Horsepower:	0.003	0.008	0.008	**0.006**
ROP Emission Limit, Grams Per Brake Horsepower[1]:	0.2	0.2	0.2	**0.2**
Drift Corrected Nitrogen Oxides Concentration (ppmvd):	34.5	34.9	35.5	**35.0**
Emission Rate, Grams Per Brake Horsepower:	0.3	0.3	0.3	**0.3**
PTI Emission Limit, Grams Per Brake Horsepower:	0.5	0.5	0.5	**0.5**
Volatile Organic Compounds (as NMOC) Concentration, Dry (ppmvd), Expressed as Propane:	0.53	0.79	0.77	**0.70**
VOC (as NMOC) Emission Rate, Grams Per Brake Horsepower:	0.004	0.006	0.006	**0.005**
PTI Emission Limit, Grams Per Brake Horsepower Hour[1]:	0.19	0.19	0.19	**0.19**

[1] The PTI CO, NO_x and VOC emission limits are more stringent than the applicable limits in 40 CFR Part 60, Subpart JJJJ, which are as follows: CO = 4.0 grams/HP-hr; NO_x = 2.0 grams/HP-hr; VOC = 1.0 grams/HP-hr

FIGURE 1

Methods 3A, 7E, 10 & 25A Sampling Apparatus Schematic

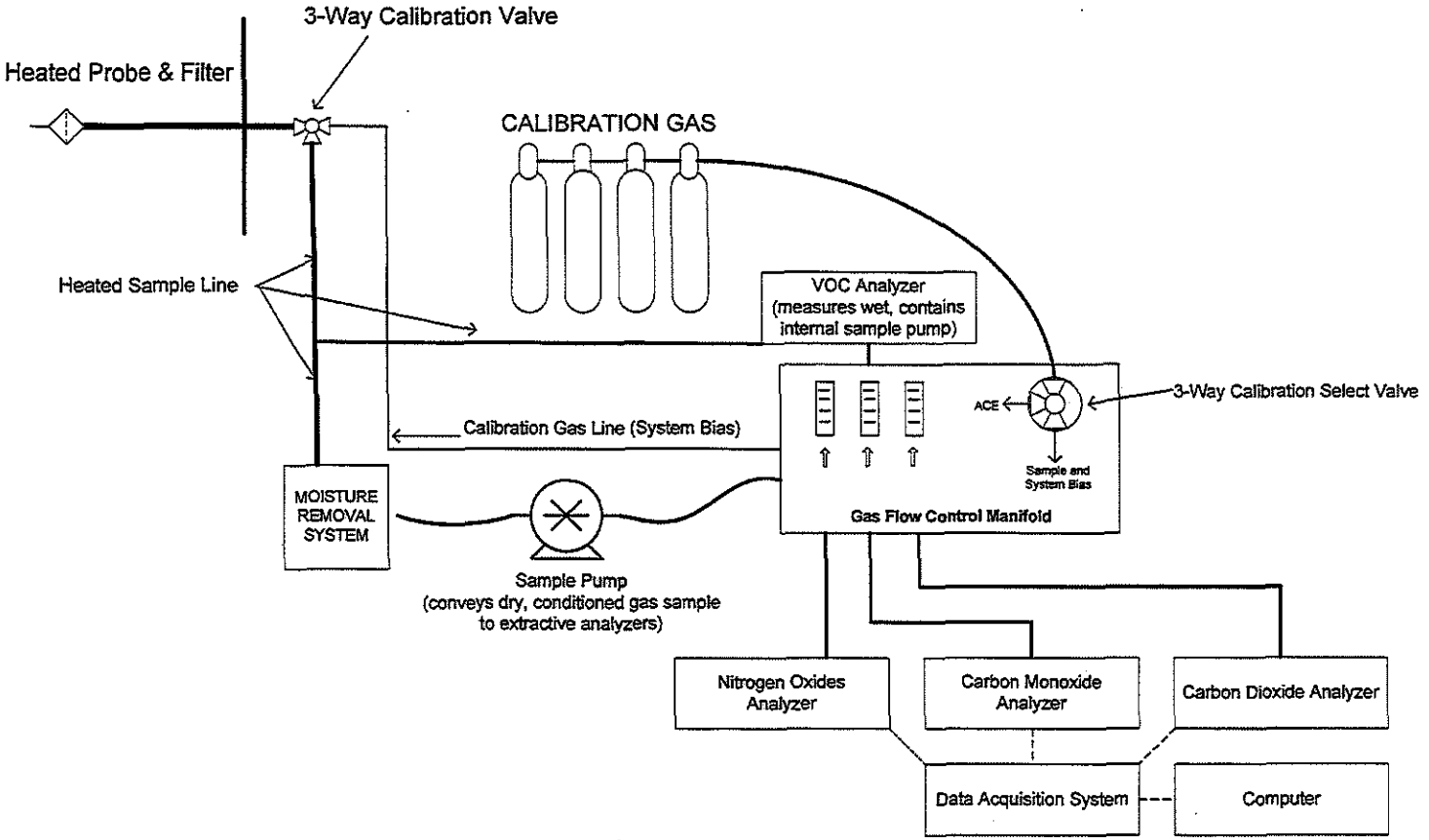
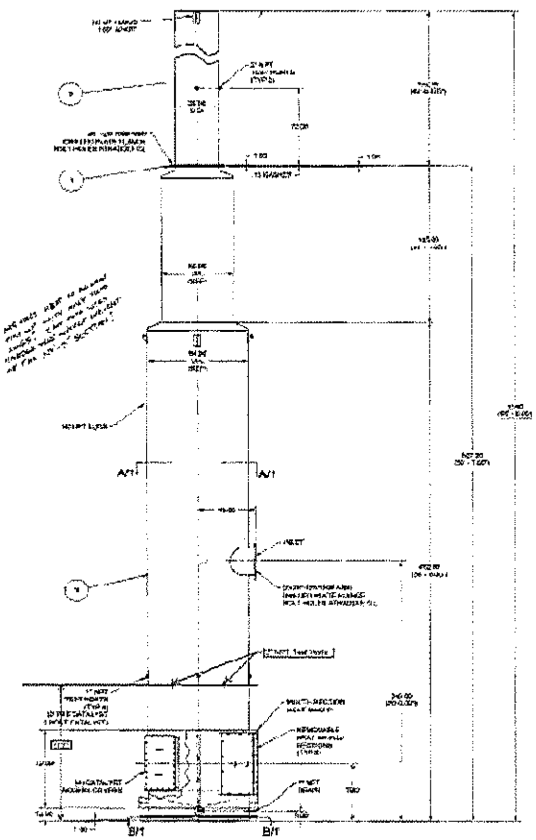


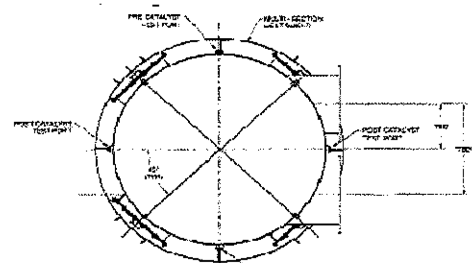
FIGURE 1

DRY AND WET EXTRACTIVE GASEOUS SAMPLE APPARATUS

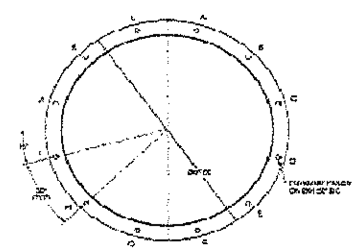
FIGURE 2

Caterpillar Model G3616 Stack Schematic (EUENGINE3-1, EUENGINE3-2, EUENGINE3-3, EUENGINE3-4 & EUENGINE3-5)





VIEW A-A/1



VIEW B-B/1

TABLE #1				
ITEM	QTY	DESCRIPTION	U.C. PART #	WEIGHT (LBS)
1	1	SILENCER / CATALYST	[illegible]	[illegible]
2	1	OUTLET STACK	[illegible]	7,000
3	1 PKG.	LOOSE PARTS	[illegible]	300
		TOTAL SYSTEM WEIGHT =		41,[illegible]

SUPPORT	DEAD LOAD	FORCE DIRECTION	WIND LOAD X	WIND LOAD Y	WIND LOAD Z	SEISMIC LOAD X	SEISMIC LOAD Y	SEISMIC LOAD Z
A	-3.5	X	1.5	—	38.2	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1
B	-3.5	X	1.5	—	38.2	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1
C	-3.5	X	1.5	—	38.2	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1
D	-3.5	X	1.5	—	38.2	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1
E	-3.5	X	1.5	—	38.2	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1
F	-3.5	X	1.5	—	[illegible]	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1
G	-3.5	X	1.5	—	38.2	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1
H	-3.5	X	1.5	—	38.2	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1
I	-3.5	X	1.5	—	38.2	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1
J	-3.5	X	1.5	—	38.2	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1
K	-3.5	X	1.5	—	38.2	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1
L	-3.5	X	1.5	—	38.2	0.6	—	13.1
		Y	—	1.5	38.2	—	0.6	13.1

Maximum overturning moment = 827 kip-ft

Horizontal shear force = 18.4 kips

NOTES:

1. ENG NO. - CAT 3616

2. [illegible]

3. CATALYST SIZE: [illegible]

COMMENTS

SOLID CATALYSTS BY
POLLUTION CONTROL ASSOCIATES INC.
CRYSTAL LAKE, IL [illegible]

UNIVERSAL SILENCER

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