Derenzo and Associates, Inc.
Environmental Consultants

AIR EMISSION TEST REPORT

Title	AIR EMISSION TEST REPORT FOR THE VERIFICATION OF NO_X EMISSION RATES FROM DUAL-FUEL BOILERS
Report Date	June 10, 2014
Test Dates	March 26 – 27 and April 17 – 18, 2014

Facility Information	
Name	Battle Creek VA Medical Center
Street Address	5500 Armstrong Road
City, County	Battle Creek, Calhoun Co., Michigan
SRN	N5984

Facility Permit Information			
Facility SRN.:	M3546	PTI No. :	187-10A

Source Information – 3 Babcock and Wilcox Co. Dual Fuel Boilers			
Emission Unit	EU-Boiler-2	EU-Boiler-3	EU-Boiler-4
Serial Number	201-3584	201-3586	201-3585

Testing Contractor	
Company	Derenzo and Associates, Inc.
Mailing Address	39395 Schoolcraft Road Livonia, MI 48150
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Project No.	1402005

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AIR EMISSION TEST REPORT FOR THE VERIFICATION OF NO_X EMISSION RATES FROM DUAL-FUEL BOILERS OPERATED AT THE BATTLE CREEK VA MEDICAL CENTER

1.0 INTRODUCTION

The Battle Creek VA Medical Center (VAMC) operates three (3) Babcock and Wilcox Company dual fueled boilers at the VAMC powerhouse facility (Facility SRN: M3546) in Battle Creek, Calhoun County, Michigan. The facility has been issued Permit to Install (PTI) No. 187-10A by the Michigan Department of Environmental Quality (MDEQ). The boilers are identified in PTI No. 187-10A as Emission Unit ID: EU-Boiler-2 through EU-Boiler-4.

Air emission compliance testing was performed to demonstrate compliance with special conditions in PTI 187-10A, for EU-Boiler-2, EU-Boiler-3 and EU-Boiler-4, which state:

> *Within 180 days after the issuance of this permit, the permitte shall verify NO_X emission rates and applicable emission factors for both natural gas and No. 2 fuel oil for* (each boiler), *by testing at owner's expense, in accordance with Department requirements ...*

The compliance testing was performed by Derenzo and Associates, Inc. (Derenzo and Associates), a Michigan-based environmental consulting and testing company. Derenzo and Associates representatives Patrick Triscari, and Andrew Rusnak performed the field sampling and measurements March 26 – 27 and April 17 – 18, 2014.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan that was reviewed and approved by the MDEQ in the March 6, 2014 test plan approval letter. MDEQ representatives Mr. David Patterson and Mr. Rex Lane observed portions of the testing project.

Questions regarding this emission test report should be directed to:

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Report Certification

I certify under penalty of law that I believe the information provided in this document is true, accurate, and complete. I am aware that there are significant civil and criminal penalties, including the possibility of fine or imprisonment or both, for knowingly submitting false, inaccurate, or incomplete information.

Report Prepared By:

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Derenzo and Associates, Inc.

Responsible Official Certification:

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Energy Manager
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2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

The VAMC operates three (3) dual fuel (natural gas or No. 2 fuel oil) boilers at the facility's powerhouse in order to provide steam to the medical center. Boiler No. 2 (EU-Boiler-2) was manufactured by the Babcock and Wilcox Company, Model No. WB-1-16. Boiler Nos. 3 and 4 (EU-Boiler-3 and EU-Boiler-4, respectively) were manufactured by the Babcock and Wilcox Company, Model No. WB-1-22.

2.2 Rated Capacities and Air Emission Controls

Boiler No. 2 has a heat input capacity of 24.14 MMBtu/hr while operating on natural gas and 23.21 MMBtu/hr while operating on fuel oil. The boiler has a rated steam output of 20,000 lb/hr.

Boiler Nos. 3 and 4 each have a heat input capacity of 48.14 MMBtu/hr while operating on natural gas and 46.28 MMBtu/hr while operating on fuel oil. Each boiler has a rated steam output of 40,000 lb/hr.

The boilers are equipped with low-NO_X design burners where combustion pollutant emissions are minimized based on proper air/fuel mixing and residence time. The boilers are not equipped with add-on emission control devices.

The fuel consumption rate is typically regulated automatically in order to maintain the proper steam load to meet the medical center's demand.

2.3 Sampling Locations

The individual boiler exhaust gas streams are directed through dedicated economizers (Boiler No. 4 has two (2) economizers) and are released to the atmosphere through dedicated vertical exhaust stacks.

The exhaust gas stream of each boiler was sampled in the square duct which exits the burner box, prior to entering the economizer.

Appendix A provides diagrams of the emission test sampling locations.

3.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

3.1 Purpose and Objective of the Tests

The conditions of PTI 187-10A require the VAMC to test each boiler (EU-Boiler-2 through EU-Boiler-4) for nitrogen oxides (NOx) emissions within 180 days of PTI issuance. Therefore, each boiler (EU-Boiler-2 through EU-Boiler-4) was sampled for NO_X emissions and exhaust gas oxygen (O_2) content while combusting natural gas and fuel oil.

3.2 Operating Conditions During the Compliance Tests

The testing was performed while each boiler was operated at maximum achievable operating conditions. Derenzo and Associates, Inc. representatives recorded the fuel usage and steam output in 15-minute increments for each test period.

Appendix B provides operating records for the test periods.

The fuel used in the boilers is either pipeline-quality natural gas or commercially-available No. 2 fuel oil, both of which have published heating values (e.g., 40 CFR Part 98 Table C-1). For natural gas, the heat input rate was determined using the measured volumetric gas flow to the boiler (scf) and the default heating value for natural gas, 1.028E-03 MMBtu/scf. For No. 2 fuel oil, the heat input rate was determined using the measured volumetric flow to the boiler (gallons) and the default heating value for No. 2 fuel oil, 0.138 MMBtu/gal.

Table 3.1 presents a summary of the average boiler operating conditions during the test periods.

3.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the sampled boilers were each sampled for three (3) one-hour test periods, while combusting natural gas and fuel oil, during the compliance testing performed March 26 – 27 and April 17 – 18, 2014.

Table 3.2 presents the average measured NO_X emission rates for the boilers (average of the three test periods for each boiler) and applicable emission limits.

Test results for each one hour sampling period and comparison to the permitted emission rates are presented in Section 6.0 of this report.

Table 3.1 Average boiler operating conditions during the test periods

Emission Unit	Fuel	Fuel Use (scfm)	Fuel Use (gal)	Heat Input (MMBtu/hr)	Steam Output (lb/hr)	Steam Load (%)
EU-Boiler-2	Natural Gas	21,961	-	22.58	17,975	89.9
EU-Boiler-3	Natural Gas	43,994	-	45.23	41,077	102.7
EU-Boiler-4	Natural Gas	38,453	-	39.53	37,416	93.5
EU-Boiler-2	No. 2 Fuel Oil	-	117.8	16.26	14,517	72.6
EU-Boiler-3	No. 2 Fuel Oil	-	315.7	43.57	43,630	109.1
EU-Boiler-4	No. 2 Fuel Oil	-	274.6	37.89	36,621	91.6

Table 3.2 Average measured emission rates for each tested VAMC boiler (three-test average)

		O_2 Content	NO_x Emission Rates	
Emission Unit	Fuel	(%)	(lb/MMBtu)	(lb/hr)
EU-Boiler-2	Natural Gas	4.01	0.03	0.71
EU-Boiler-3	Natural Gas	3.66	0.03	1.46
EU-Boiler-4	Natural Gas	4.86	0.04	1.39
EU-Boiler-2	No. 2 Fuel Oil	5.99	0.11	1.77
EU-Boiler-3	No. 2 Fuel Oil	4.65	0.10	4.53
EU-Boiler-4	No. 2 Fuel Oil	4.69	0.10	3.86
Emission Limit	-	-	0.05	1.23 / 2.47*

* - Boiler No. 2 emission limit is 1.23 lb/hr, Boiler Nos. 3 and 4 emission limits are 2.47 lb/hr

4.0 SAMPLING AND ANALYTICAL PROCEDURES

Test protocols for the air emission testing were reviewed and approved by the MDEQ. This section provides a summary of the sampling and analytical procedures that were used during the testing periods.

4.1 Summary of Sampling Methods

USEPA Method 3A	Exhaust gas O_2 content was determined using a paramagnetic instrumental analyzer.
USEPA Method 7E	Exhaust gas NOx concentration was determined using chemiluminescence instrumental analyzers.
USEPA Method 19	Mass emission rate calculation based on fuel F-factor

4.2 Exhaust Gas Oxygen Content (USEPA Method 3A)

O_2 content in the boiler exhaust gas streams was measured continuously throughout each test period in accordance with USEPA Method 3A. The O_2 content of the exhaust was monitored using a Servomex 4100 or 4900 gas analyzer that uses a paramagnetic sensor.

During each sampling period, a continuous sample of the boiler exhaust gas stream was extracted from the exhaust duct using a stainless steel probe connected to a Teflon® heated sample line. The sampled gas was conditioned by removing moisture prior to being introduced to the analyzers; therefore, measurement of O_2 concentrations correspond to standard dry gas conditions. Instrument response data were recorded using an ESC Model 8816 data acquisition system that monitored the analog output of the instrumental analyzers continuously and logged data as one-minute averages.

Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias (described in Section 5.0 of this document). Sampling times were recorded on field data sheets.

Appendix C provides O_2 calculation sheets. Raw instrument response data are provided in Appendix D.

4.3 NO_x Concentration Measurements (USEPA Method 7E)

NO_x pollutant concentrations in the boiler exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42c High Level chemiluminescence NO_X analyzer.

Throughout each test period, a continuous sample of the boiler exhaust gas was extracted from the stack using the Teflon® heated sample line and gas conditioning system and delivered to the

instrumental analyzers. Instrument response for each analyzer was recorded on an ESC Model 8816 data acquisition system that logged data as one-minute averages. Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias.

Appendix C provides NO_X calculation sheets. Raw instrument response data are provided in Appendix D.

4.4 Mass Emission Rate Calculations (USEPA Method 19)

The NO_x mass emission rate (lb/MMBtu and lb/hr) was calculated using the measured NO_x concentration and appropriate fuel F factors (ratio of combustion gas volume to heat input) as described in USEPA Method 19.

The fuel used in the dual fuel boilers was natural gas and No. 2 fuel oil, both of which have published default F-factor in USEPA Method 19, Table 19-2. Exhaust gas oxygen content and NO_x concentration were each measured on a dry gas basis. Therefore, the NO_x emission factor, E (lb/MMBtu) was calculated using Equation 19-1:

$$E = (C_d) \times (F_d) \times (20.9) / (20.9 - \%O_2)$$

E	=	Calculated NO_x emission factor, lb/MMBtu
C_d	=	Measured NO_x concentration, dry basis, lb/scf
F_d	=	8,710 dscf/MMBtu for natural gas
F_d	=	9,190 dscf/MMBtu for crude, residual or distillate oil
$\%O_2$	=	Measured oxygen content, dry basis, %vol.

The hourly NO_x mass emission rate (lb/hr) for each test period was calculated using the NO_x emission factor (E, lb/MMBtu) and the calculated heat input rate (heat input rate was calculated using recorded fuel usages and fuel heat contents specified in Section 3.2).

$$E_R = (H_b) \times (E)$$

E_R	=	Calculated NO_X emission rate, lb/hr
H_b	=	Heat input rate to the boiler from fuel, MMBtu/hr
E	=	Calculated NO_X emission rate, lb/MMBtu

5.0 QA/QC ACTIVITIES

5.1 NO_x Converter Efficiency Test

The NO_2 – NO conversion efficiency of the Model 42c analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO_2 was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO_2 – NO converter uses a catalyst at high temperatures to convert the NO_2 to NO for measurement. The conversion efficiency of the analyzer is deemed acceptable if the measured NO_2 concentration is within 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_2 concentration was -8.73% (March 25) and -7.60% (April 16) of the expected value, i.e., within 10% of the expected value as required by Method 7E).

5.2 Sampling System Response Time Determination

The response time of the sampling system was determined prior to the compliance test program by introducing upscale gas and zero gas, in series, into the sampling system using a tee connection at the base of the sample probe. The elapsed time for the analyzer to display a reading of 95% of the expected concentration was determined using a stopwatch.

The TEI Model 42c analyzer exhibited the longest system response time at 71 seconds. Results of the response time determinations were recorded on field data sheets. For each test period, test data were collected once the sample probe was in position for at least twice the maximum system response time.

5.3 Gas Divider Certification (USEPA Method 205)

A STEC Model SGD-710C 10-step gas divider was used to obtain appropriate calibration span gases. The ten-step STEC gas divider was NIST certified (on December 20, 2013) with a primary flow standard in accordance with Method 205. When cut with an appropriate zero gas, the ten-step STEC gas divider delivered calibration gas values ranging from 0% to 100% (in 10% step increments) of the USEPA Protocol 1 calibration gas that was introduced into the system. The field evaluation procedures presented in Section 3.2 of Method 205 were followed prior to use of gas divider. The field evaluation yielded no errors greater than 2% of the triplicate measured average and no errors greater than 2% from the expected values.

5.4 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NO_X and O_2 have had an interference response test preformed prior to their use in the field (July 26, 2006, June 21, 2011 and April 3, 2012), pursuant to the interference response test procedures specified in USEPA Method 7E. The appropriate interference test gases (i.e., gases that would be encountered in the exhaust gas stream) were

introduced into each analyzer, separately and as a mixture with the analyte that each analyzer is designed to measure. All of analyzers exhibited a composite deviation of less than 3.0% of the span for all measured interferent gases. No major analytical components of the analyzers have been replaced since performing the original interference tests.

5.5 Instrument Calibration and System Bias Checks

At the beginning of each day of the testing program, initial three-point instrument calibrations were performed for the NO_x, and O_2 analyzers by injecting calibration gas directly into the inlet sample port for each instrument. System bias checks were performed prior to and at the conclusion of each sampling period by introducing the upscale calibration gas and zero gas into the sampling system (at the base of the stainless steel sampling probe prior to the particulate filter and Teflon® heated sample line) and determining the instrument response against the initial instrument calibration readings.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of O_2 and NO_x, in nitrogen and zeroed using hydrocarbon free nitrogen. A STEC Model SGD-710C ten-step gas divider was used to obtain intermediate calibration gas concentrations as needed.

5.6 Determination of Exhaust Gas Stratification

A stratification test for each boiler exhaust duct and each fuel (i.e., two stratification checks per boiler) was performed during the performance test sampling periods. The stainless steel sample probe was positioned at sample points correlating to 16.7, 50.0 (centroid) and 83.3% of the duct width. Pollutant concentration data were recorded at each sample point for a minimum of twice the maximum system response time.

The recorded data for each boiler exhaust duct gas indicate that the measured NO_x concentrations did not vary by more than 5% of the mean across the stack width. Therefore, the stack gas of each boiler was considered to be unstratified and the compliance test sampling was performed at a single sampling location within each boiler exhaust duct.

Appendix E presents test equipment quality assurance data (NO_2 – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas and gas divider certifications, interference test results and stratification checks).

6.0 RESULTS

6.1 Test Results and Allowable Emission Limits

Boiler operating data and air pollutant emission measurement results for each one hour test period are presented in Tables 6.1 through 6.6.

The measured air pollutant concentrations and emission rates while combusting natural gas for Boiler Nos. 2 – 4 (EU-Boiler-2 through EU-Boiler4) are less than the allowable limits specified

in PTI No. 187-10A for the boilers. The measured air pollutant concentrations and emission rates while combusting No. 2 fuel oil for Boiler Nos. 2 – 4 (EU-Boiler-2 through EU-Boiler4) are greater than the allowable limits specified in PTI No. 187-10A for the boilers:

- 1.23 lb/hr and 0.05 lb/MMBtu for NO_x emitted from Boiler No. 2; and
- 2.47 lb/hr and 0.05 lb/MMBtu for NO_x emitted from Boiler Nos. 3 or 4.

6.2 Variations from Normal Sampling Procedures or Operating Conditions

Upon completion of the natural gas portion of the testing program (on March 27, 2014) VAMC boiler operators were unable to sustain combustion while firing fuel oil. Boiler No. 2 was tested while combusting No. 2 fuel oil on March 27, 2014, however, the fuel flow to the boiler was highly restricted (results from these discarded test runs are presented in Appendix C). Testing was postponed until April 17, 2014 in order to troubleshoot the problem.

It was determined that the fuel oil valve on Boiler No. 4 had a hole in it's diaphragm and that debris in the No. 2 fuel oil storage tank was clogging the No. 2 fuel oil filters and slowly choking off the fuel supply to the boilers. Larger fuel oil filters were ordered and more frequent filter changes allowed for the No. 2 fuel oil portion of the testing program to be completed on April 17 and 18, 2014. During the first test run performed on Boiler No. 4 and the second test run performed on Boiler No. 3 testing was paused midway through the run in order to change out the fuel filter. This was discussed and approved by MDEQ representatives.

Table 6.1 Measured exhaust gas conditions and NO_x air pollutant emission rates VA Medical Center Boiler No. 2 – Natural Gas Combustion (EU-Boiler-2)

Test No.	1	2	3	
Test date	3/26/14	3/26/14	3/26/14	Three Test
Test period (24-hr clock)	1335 - 1435	1507 - 1607	1620 – 1720	Average
Steam Load (%)	89.5	90.7	89.4	89.9
Steam Output (lb/hr)	17,892	18,149	17,884	17,975
Fuel Use (scfh)	21,950	21,947	21,987	21,961
Heat Input (MMBtu/hr)	22.56	22.56	22.60	22.58
Exhaust Gas Composition				
O_2 content (% vol)	3.60	4.35	4.08	4.01
Nitrogen Oxides				
NO_X conc. (ppmvd)	24.9	23.9	24.3	24.4
NO_X emissions (lb/MMBtu)	0.03	0.03	0.03	0.03
Permitted emissions (lb/MMBtu)	-	-	-	0.05
NO_X emissions (lb/hr)	0.71	0.71	0.71	0.71
Permitted emissions (lb/hr)	-	-	-	1.23

Table 6.2 Measured exhaust gas conditions and NO_x air pollutant emission rates VA Medical Center Boiler No. 3 – Natural Gas Combustion (EU-Boiler-3)

Test No.	1	2	3	
Test date	3/26/14	3/26/14	3/26/14	Three Test
Test period (24-hr clock)	933 - 1033	1058 - 1158	1209 – 1309	Average
Steam Load (%)	101.5	101.9	104.7	102.7
Steam Output (lb/hr)	40,584	40,749	41,898	41,077
Fuel Use (scfh)	43,831	43,996	44,156	43,994
Heat Input (MMBtu/hr)	45.06	45.23	45.39	45.23
Exhaust Gas Composition				
O_2 content (% vol)	3.67	3.66	3.64	3.66
Nitrogen Oxides				
NO_X conc. (ppmvd)	26.1	25.4	25.4	25.6
NO_X emissions (lb/MMBtu)	0.03	0.03	0.03	0.03
Permitted emissions (lb/MMBtu)	-	-	-	0.05
NO_X emissions (lb/hr)	1.48	1.45	1.45	1.46
Permitted emissions (lb/hr)	-	-	-	2.47

Table 6.3 Measured exhaust gas conditions and NO_x air pollutant emission rates VA Medical Center Boiler No. 4 – Natural Gas Combustion (EU-Boiler-4)

Test No.	1	2	3	
Test date	3/27/14	3/27/14	3/27/14	Three Test
Test period (24-hr clock)	814 - 914	938 - 1038	1109 - 1209	Average
Steam Load (%)	102.8	91.7	86.1	93.5
Steam Output (lb/hr)	41,132	36,680	34,435	37,416
Fuel Use (scfh)	39,345	38,164	37,851	38,453
Heat Input (MMBtu/hr)	40.45	39.23	38.91	39.53
Exhaust Gas Composition				
O_2 content (% vol)	4.59	4.93	5.05	4.86
Nitrogen Oxides				
NO_X conc. (ppmvd)	26.2	26.2	25.4	26.0
NO_X emissions (lb/MMBtu)	0.03	0.04	0.03	0.04
Permitted emissions (lb/MMBtu)	-	-	-	0.05
NO_X emissions (lb/hr)	1.41	1.40	1.36	1.39
Permitted emissions (lb/hr)	-	-	-	2.47

Table 6.4 Measured exhaust gas conditions and NO_x air pollutant emission rates VA Medical Center Boiler No. 2 – No. 2 Fuel Oil Combustion (EU-Boiler-2)

Test No.	1	2	3	
Test date	4/17/14	4/17/14	4/17/14	Three Test
Test period (24-hr clock)	854 - 954	1009 - 1109	1121 - 1221	Average
Steam Load (%)	86.7	73.5	57.6	72.6
Steam Output (lb/hr)	17,335	14,694	11,523	14,517
Fuel Use (gal/hr)	143.9	119.7	89.6	117.8
Heat Input (MMBtu/hr)	19.86	16.52	12.36	16.26
Exhaust Gas Composition				
O_2 content (% vol)	5.41	6.47	6.10	5.99
Nitrogen Oxides				
NO_X conc. (ppmvd)	64.1	72.7	79.5	72.1
NO_X emissions (lb/MMBtu)	0.10	0.12	0.12	0.11
Permitted emissions (lb/MMBtu)	-	-	-	0.05
NO_X emissions (lb/hr)	1.88	1.91	1.52	1.77
Permitted emissions (lb/hr)	-	-	-	1.23

Table 6.5 Measured exhaust gas conditions and NO_x air pollutant emission rates VA Medical Center Boiler No. 3 – No. 2 Fuel Oil Combustion (EU-Boiler-3)

Test No.	1	2	3	
Test date	4/18/14	4/18/14	4/18/14	Three Test
Test period (24-hr clock)	1142 - 1242	1256 - 1521	1535 – 1635	Average
Steam Load (%)	108.6	109.3	109.3	109.1
Steam Output (lb/hr)	43,424	43,730	43,734	43,630
Fuel Use (gal/hr)	311.6	315.1	320.4	315.7
Heat Input (MMBtu/hr)	43.00	43.48	44.22	43.57
Exhaust Gas Composition				
O_2 content (% vol)	4.53	4.63	4.78	4.65
Nitrogen Oxides				
NO_X conc. (ppmvd)	72.9	74.6	73.7	73.7
NO_X emissions (lb/MMBtu)	0.10	0.11	0.10	0.10
Permitted emissions (lb/MMBtu)	-	-	-	0.05
NO_X emissions (lb/hr)	4.39	4.57	4.63	4.53
Permitted emissions (lb/hr)	-	-	-	2.47

Table 6.6 Measured exhaust gas conditions and NO_x air pollutant emission rates VA Medical Center Boiler No. 4 – No. 2 Fuel Oil Combustion (EU-Boiler-4)

Test No.	1	2	3	
Test date	4/17/14	4/17/14	4/17/14	Three Test
Test period (24-hr clock)	1244 - 1416	1433 - 1533	1552 - 1652	Average
Steam Load (%)	97.7	76.1	100.8	91.6
Steam Output (lb/hr)	39,083	30,443	40,338	36,621
Fuel Use (gal/hr)	300.7	235.1	288.1	274.6
Heat Input (MMBtu/hr)	41.50	32.44	39.76	37.89
Exhaust Gas Composition				
O_2 content (% vol)	4.71	4.79	4.57	4.69
Nitrogen Oxides				
NO_X conc. (ppmvd)	73.0	67.5	74.8	71.8
NO_X emissions (lb/MMBtu)	0.10	0.10	0.11	0.10
Permitted emissions (lb/MMBtu)	-	-	-	0.05
NO_X emissions (lb/hr)	4.29	3.12	4.18	3.86
Permitted emissions (lb/hr)	-	-	-	2.47