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New Technology Research & Development Program
Grant Contract 582-5-70807-T036

Final Deliverable Report

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by the State of Texas through a Grant from the
Texas Commission on Environmental Quality.

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World Energy B20 Envirodiesel® Evaluation as a TCEQ Alternative Fuel Formulation

Presented to:

Glenn Shankle
Executive Director
Texas Commission on Environmental Quality
12100 Park 35 Circle
Austin, TX 78753

On Behalf of:

Graham Noyes
World Energy Alternatives, LLC
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Prepared by:

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December 27, 2006

Revision History

Ver 1 – December 11, 2006

Ver 2 – December 27, 2006: Added NMHC Data

Ver 3 – Addressed Dr. Shades QA/QC review comments/questions (comments/questions and authors response contained in Appendix B)

December 11, 2006

Mr. Glenn Shankle

Executive Director

Texas Commission on Environmental Quality

12100 Park 35 Circle

Austin, Texas 78753

Re: World Energy Alternatives, LLC Alternative Fuel Formulation Test Report

Dear Mr. Shankle:

On November 17th, 2006, the Texas Commission on Environmental Quality approved the test protocol submitted by West Virginia University, on behalf of World Energy Alternatives, LLC, for the testing of a formulation of 80% (by volume) TxLED reference fuel, 20% (by volume) of World Energy Envirodiesel®, and 0.125% (by volume) 2 ethyl-hexyl nitrate pursuant to 30 T.A.C. §114.315(c) for the purpose of determining emissions equivalency to Texas Low Emission Diesel . Pursuant to this approval, testing was conducted at the Engines and Emissions Research Laboratory at West Virginia University between November 17th and November 21st, 2006. Enclosed is a report titled, "Test Results: World Energy B20 Envirodiesel® Evaluation as a TCEQ Alternative Fuel Formulation".

If you have any questions, please contact me at (304) 293-3111, ext. 2468.

Sincerely,

David McKain

cc: Morris Brown

Joseph Walton

West Virginia University
Department of Mechanical and Aerospace Engineering

January 2, 2007

Glen Shankle
Executive Director
Texas Commissions on Environmental Quality
12100 Park 35 Circle
Austin, TX 78573

Mr. Shankle,

I have performed a Quality Assurance and Quality Control (QA/QC) review of both the content and the data contained in the report entitled "World Energy B20 Envirodiesel® Evaluation as a TCEQ Alternative Fuel Formulation," submitted by West Virginia University's Center for Alternative Fuels, Engines and Emissions on behalf of World Energy Alternatives, LLC.

I have found that the engine and emissions data included in the final report are consistent with the engine and emissions data that are included in the laboratory short reports for the tests that were conducted.

I have reviewed the procedures and calibration documentation for the study and have found no errors that would potentially impact the results of the study.

The results of my QA/QC review allow me to believe that the results included in the final report and the statistical analysis reported in accordance with TAC §114.315(c)(5) as shown in the final report are in agreement with the raw laboratory data.

Respectfully submitted,

Benjamin C. Shade

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Approval Sheet

Nigel N. Clark, Principal Investigator	1/3/07. Date
Benjamin Shade, Project Quality Review	01/04/07 Date
David L. McKain, Lead Engineer	1/3/07 Date

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Test Results: Evaluation and Optimization of Compression Ignition Engine Emission from Biodiesel Fuel Blends with Additive Levels, World Energy B20 Envirodiesel® Evaluation as a TCEQ Alternative Fuel Formulation

Presented to:

Glenn Shankle
Executive Director
Texas Commission on Environmental Quality
12100 Park 35 Circle
Austin, TX 78753

On Behalf of:

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Prepared by:

David McKain
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December 11, 2006

Introduction

The West Virginia University (WVU) Engine and Emissions Research Laboratory (EERL) evaluated the emissions from a 1992 Detroit Diesel Corporation Series 60 diesel engine for a Texas reference diesel fuel meeting Texas Low Emission Diesel requirements as specified in the Texas Administrative Code (TAC) §114.315 (termed "Reference fuel") and an alternative diesel fuel formulation candidate diesel fuel composed of 80% (by volume) reference fuel, 20% (by volume) World Energy Envirodiesel®, and 0.125% (by volume) 2 ethyl-hexyl nitrate (termed "Candidate fuel"). The objective of this evaluation was to compare the emissions and performance of the Candidate fuel to that of the Reference fuel. Emissions of oxides of nitrogen (NOx), total particulate matter (TPM), carbon monoxide (CO), total hydrocarbons (THC), carbon dioxide (CO_2), and non-methane hydrocarbons (NMHC) along with fuel consumption (FC) were measured while the engine was exercised over the Federal Test Procedure (FTP) engine test cycle and are reported on a brake-specific basis (per bhp-hr). The evaluation of both fuels followed the procedures outlined in the Code of Federal Regulations (CFR) Title 40 Part 86 [1]. However, only the results of hot start tests were used for the comparison.

The preparation of this report is based on work funded in part by the State of Texas through a Grant from the Texas Commission on Environmental Quality (TCEQ).

Laboratory Description

The fuel tests were performed using a 1992 Detroit Diesel Corporation Series 60 engine (model number: 6067GU60, serial number: 06R0105610) mounted to a 550 hp General Electric dynamometer located in the EERL at WVU. Engine exhaust was ducted to a full-scale dilution tunnel (18 inches in diameter, 20 feet in length) with flow control accomplished using a critical flow venturi-constant volume sampler (CFV-CVS) system. A 10-inch diameter orifice, located 3 feet from the tunnel entrance, ensured that exhaust was thoroughly mixed with dilution air before it reached the emissions sampling zone, located ten tunnel diameters downstream. The CFV-CVS controlled the dilute exhaust flow at a nominal 2400 scfm throughout the test program. Instantaneous measurement of CFV-CVS flow was accomplished using a fast-response thermocouple and pressure transducer at the venturi entrance. Dilute exhaust sample were drawn from the tunnel using heated sample probes and lines to individual emissions analyzers. Dilute exhaust was also drawn from the dilution tunnel sample plane through series 70mm filters to obtain particulate matter samples. Temperature and humidity of the engine and dilution tunnel intake air was controlled to 77+/-5 degrees F and 50+/-5% for the duration of the testing.

Measurement of carbon monoxide (CO) and carbon dioxide (CO2) emissions were performed using non-dispersive infrared (NDIR) analyzers while oxides of nitrogen (NOx) and hydrocarbons (THC) were measured, respectively, using a wet chemiluminescent analyzer and heated flame ionization detector (HFID). A Varian 3600 gas chromatograph was used to measure the NMHC concentrations from gas sample bags taken during the testing [2]. The gas analysis bench was equipped with exhaust sample conditioning and analysis systems following CFR 40 Part 86 requirements. Data from the exhaust analyzers, sampling trains, double dilution tunnel, and the engine were acquired and archived at a rate of 5 Hz.

Particulate matter (PM) was measured using a proportional sampling system. Dilute exhaust was drawn from the main dilution tunnel into a stainless steel 4-inch diameter by 30-inch long secondary dilution tunnel and, in turn, was drawn through a stainless steel filter holder that contained two Pallflex 70mm diameter Model T60A20 fluorocarbon-coated glass microfiber filters in series. The sample stream was maintained at temperatures below 125 ºF and measured at the inlet of the TPM filter holder. Secondary

dilution air, which can be used to lower the temperature of the dilute sample upstream of the sample filters, was not required during this evaluation. Prior to weighing (both before and after use) sample filters were conditioned in an environmentally controlled room to a nominal 22 ºC dry bulb, 9.5 ºC dew point, and 45% relative humidity, in compliance with requirements as specified in CFR 40 Part 86. Filters were weighed using a Sartorius microbalance. To minimize the contribution of background particulate matter on dilute exhaust PM measurements, dilution air was drawn through HEPA filters located in the intake conditioning system. These HEPA filters, each at a 2400 cfm capacity, were placed in parallel to provide up to 4800 cfm capacity.

Calibration procedures and intervals were followed according to CFR 40 Part 86 requirements. A laboratory checkout following the procedures listed in CFR 40 Part 86 was performed prior to the collection of the data.

Additionally, the engine was instrumented for speed, torque, throttle position, manifold air pressure, air intake restriction, total exhaust backpressure, manifold intake temperature, coolant temperature, oil temperature, and exhaust temperature according to CFR 40 Part 86 requirements.

Test Fuels and Oil

The reference fuel used for this evaluation was obtained from Chevron-Philips. The fuel was delivered in eight 55 gallon drums, the contents of which were transferred to a 600 gallon stainless steel mixing tank. After circulating the fuel in the mixing tank for approximately 1 hour, the contents were transferred back into the 55 gallon drums and placed in a fuel storage facility. A one gallon sample of the reference fuel was delivered to Saybolt in Carson, CA for analysis, the results of which are in Appendix A.

The components to blend the World Energy Envirodiesel® were delivered to WVU in five gallon plastic buckets. The contents of the buckets were transferred into a 55 gallon drum where they were circulated by an external pump at 10 gallons per minute for approximately 30 minutes to ensure proper mixing. A one-gallon sample of the Envirodiesel® was shipped to World Energy who subsequently shipped it to Interscope of Pasadena, TX for analysis (Appendix A) prior to initiating the evaluation. At the request of TCEQ, WVU obtained a 1 gallon sample of Envirodiesel® used to prepare the candidate fuel in the presence of a TCEQ observer. This one gallon sample was subsequently shipped to Saybolt of Carson, CA for analysis (results of analysis in Appendix A).

The additive used during this evaluation, 2-EHN, was received by WVU in a 5 gallon steel drum.

The candidate fuel was prepared by mixing 80% (by volume) of the reference fuel with 20% (by volume) of the Envirodiesel® blend stock and adding 0.125% 2-EHN to that mixture. The candidate fuel was prepared in 16 gallon stainless steel drums and, after the addition of the 2-EHN, was rolled back-and-forth on the floor over a nominal 10 foot path a total of 30 times to ensure adequate mixing. Prior to applying for approval to start the evaluation program, WVU prepared 5 gallons of candidate fuel (without 2-EHN) such that analysis could be performed by Saybolt of Carson, CA (results of analysis in Appendix A).

The engine oil and oil filters had been changed within 100 hours of the beginning of this evaluation program. The engine oil was commercially availble 15W-40 diesel specification engine oil.

Fuel Preparation

The Candidate fuel will be prepared prior to testing by mixing 80% (by volume) of the Reference fuel stock with 20% (by volume) of the B100 blend stock. A scale accurate to 0.05lb was utilized to perform

fuel measurements and the following calculations were performed to determine the required mass of reference and candidate fuel required to obtain a 20% by volume mixture:

$Density_{Reference}$ = 0.831 g/ml

$Density_{B100}$ = 0.879 g/ml

Mass Ratio = 80% * $Density_{Reference}$ / 20% * $Density_{B100}$

= (0.8 * 0.831) / (0.2 * 0.879)

= 3.782

$M_{Reference}$ = Mass Ratio * M_{B100}

$M_{Candidate}$ = $M_{Reference}$ + M_{B100}

= Mass Ratio * M_{B100} + M_{B100}

=(Mass Ratio + 1) * M_{B100}

WVU prepared separate batches of candidate fuel in 16 gallon stainless steel drums, each batch having a weight of 100lbs. The calculations performed to obtain the required weight of reference fuel and biodiesel blend stock (B100) are as follows.

100lbs = (3.782 + 1) * M_{B100} = 4.782 * M_{B100}

M_{B100} = 100 / 4.782 = 20.91lbs B100

$M_{Reference}$ = Mass Ratio * M_{B100}

= 3.782 * 20.91 lbs

= 79.09 lbs

Final Volume = $M_{Reference}$ / $Density_{Reference}$ + M_{B100} / $Density_{B100}$

= 79.09 lbs * (453.6 grams / lb) / 0.831 g/ml

+ 20.91 lbs * (453.6 grams / lb) / 0.879 g/ml

= 43122 ml + 10790 ml

= 53912 ml (14.24 gallons)

Where the final specific gravity of the Candidate fuel is calculated in the following manner:

$Denisty_{Candidate}$ = $M_{Candidate}$ / $V_{Candidate}$

= (100 lbs * 453.6 grams / lb) / 53912 ml

= 0.841 g/ml

To obtain amount of 2EHN additive required to raise the B20 fuel to the required 0.125% (by volume), the following calculations were performed:

V_{2EHN} = 0.125% * V_{B20}

For the 100lbs of B20 prepared, a volume of 52.7 ml was required to raise the 2EHN concentration to 0.125%.

Test Procedure

Evaluation of the emissions was conducted using the 1992 Detroit Diesel Corporation Series 60 engine described previously which was inspected prior to use in this study. The inspection included visual examination and measurement of engine parameters and review of data from the engine control unit. A Nexiq Technologies Prolink Plus monitor was used to display the engine control unit data and to display any potential problems (error codes) during this testing. In addition, the continuous broadcast of the public messages from the SAE J1708/1587 data link were captured using B&B Electronics VIA HPV100A1 protocol adaptor. There were no error codes generated during this entire testing campaign.

The engine operating parameters were set to within the specifications listed in CFR 40 Part 86 or listed by the engine manufacturer for engine dynamometer testing. An ascending speed engine map (lug curve) was then generated using the Reference fuel for use in generating the FTP speed-time and torque-time traces used for the entire test program. To ensure that the engine was operating in the same fashion as on the first test day, at least two engine maps were performed after each fuel change and at the beginning of each test day.

The engine description is listed in Table 1 and the engine map used for the engine load setpoint is shown in Figure 1. The engine torques at selected speeds along with the average and coefficient of variance for the reference fuel on the first day of testing are shown in Table 2.

Table 1 Test engine specifications.

Engine Manufacturer	Detroit Diesel Corp.
Engine Model	Series 60
Model Year	1992
Displacement (liters)	12.7
Power Rating (hp)	360 @ 1810 rpm
Configuration	Inline 6
Bore (in.) x Stroke (in.)	5.12 x 6.30
Induction	Turbocharger with Aftercooler
Fuel Type	Diesel
Engine Strokes per Cycle	Four
Injection	Direct, Electronic

Table 2 Measured engine speed-torque points from Day 1 reference fuel maps (Map #4 – E01531 was used to generate FTP the speed-time and torque-time cycles used for all subsequent testing).

	Torque (ft-lbf)					
Speed (rpm)	**Map #1 E01531-91**	**Map #2 E01531-92**	**Map #3 E01531-93**	**Map #4 E01531-94**	**Average**	**COV**
625	643.7	649.2	642.8	653.8	647.4	0.8%
700	696.4	689.0	681.0	687.9	688.6	0.9%
800	670.3	668.9	670.2	672.6	670.5	0.2%
900	836.7	839.8	835.6	839.9	838.0	0.3%
1000	1035.3	1027.1	1020.4	1038.5	1030.4	0.8%
1100	1199.1	1207.5	1212.1	1210.2	1207.2	0.5%
1200	1340.0	1336.3	1330.9	1332.9	1335.0	0.3%
1300	1314.8	1312.1	1312.9	1310.4	1312.6	0.1%
1400	1274.0	1276.7	1274.6	1273.3	1274.7	0.1%
1500	1264.8	1258.8	1264.8	1262.1	1262.6	0.2%
1600	1205.5	1204.8	1209.2	1206.2	1206.4	0.2%
1700	1134.1	1132.0	1130.8	1133.1	1132.5	0.1%
1800	1079.8	1077.9	1078.0	1078.3	1078.5	0.1%
1900	423.7	422.7	422.7	422.9	423.0	0.1%
2000	-171.3	-171.3	-170.3	-170.7	-170.9	-0.3%

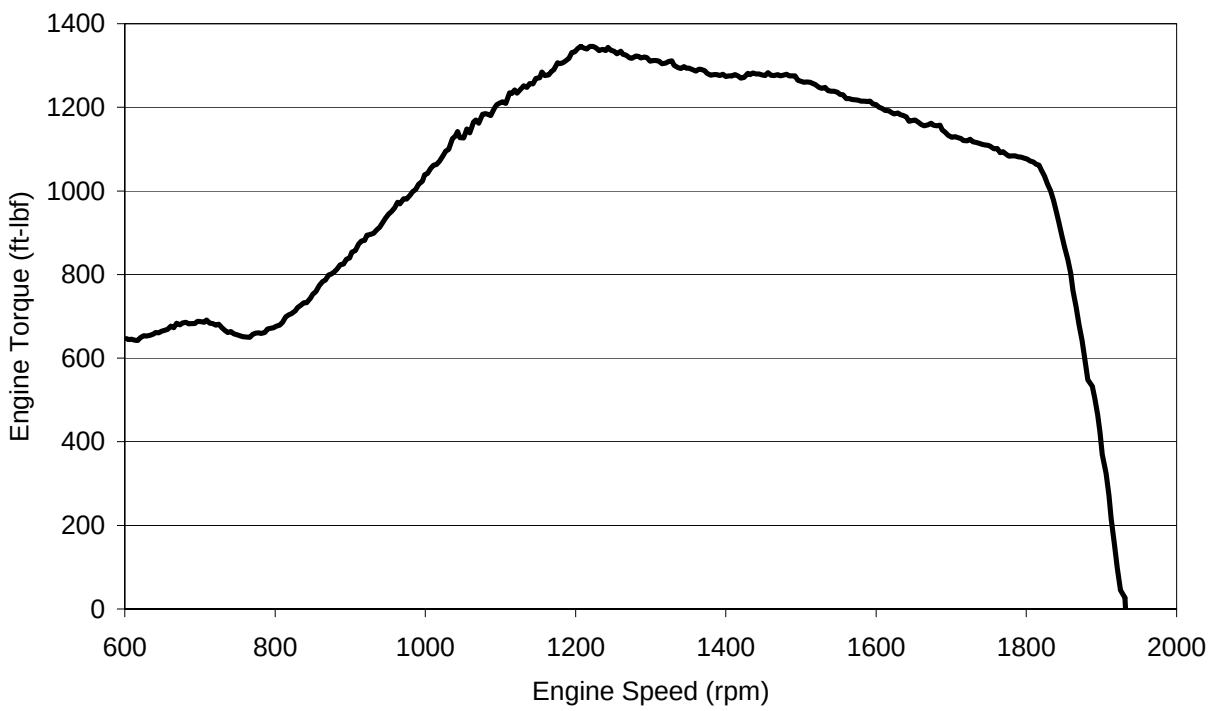

Figure 1 1992 DDC S60 engine lug curve (Day 1 reference fuel map #4).

Before and after each test, the response of the emissions analyzers to reference gases of 0% and 100% of their respective analyte were checked and recorded and, in cases where an analyzer required zero/span

adjustment, that event was recorded. It is noted that there were no significant (greater than two percent) drift problems encountered in the analyzers or sampling system during this study.

During each test day, a 20-minute tunnel background test was performed to collect background particulate matter emissions. These background PM levels were used to correct each FTP test performed on that day. It is noted that, while the HEPA filters located at the intake to the dilution tunnel air conditioning system significantly reduced the ambient TPM contribution, HEPA filters are only 99.97% efficient at 0.3 μm and their efficiencies at other particle sizes are dependant upon the filter loading history. Also, tunnel shedding does still occur and is most likely the largest contributor to the tunnel background.

The Fuel was supplied to the test engine directly from the 16 gallon stainless steel drums used to prepare the candidate fuel and, in the case of the reference fuel, the same 16 gallon stainless steel drum was used throughout the testing and refilled as needed from the 55 gallon reference fuel drums. The engine fueling system was comprised of a primary loop which circulated fuel from the 16 gallon drum to provide a nominal 20 psi pressure to a secondary loop. The secondary loop was circulated using the engine lift pump. The primary loop supplied fuel to make up the volume in the secondary loop used by the engine. To prevent cross contamination of the fuels when switching from one fuel to another, the primary loop draw tube was removed from the 16 gallon drum and the primary loop pump activated such that excess fuel in that loop was returned to the drum. Once the primary loop was emptied, the primary loop return line was disconnected from the 16 gallon drum and routed to a 5 gallon waste bucket while the primary loop draw tube was place in the new 16 gallon drum. The primary loop pump was then energized such that the new fuel would circulate into the primary loop to both fill and flush the primary loop components (filter/lines/pump). During this flushing operation, the color of the fuel being flushed into the waste bucked was visually monitored for a color change and the weight of the 16 gallon fuel drum was monitored. Upon a color change (which indicated that the new fuel had displaced any fuel remaining in the primary loop), a nominal 0.5 gallons of the new fuel was allowed to flush through the primary loop prior to routing the return line back into the 16 gallon drum. The secondary system was flushed in a similar manner with the exceptions that 1) the secondary loop was not emptied during the fuel change; 2) an isolation valve was closed to prevent circulation back to the intake of the external secondary loop pump and; 3) a flush line was connected immediately upstream of the isolation valve to draw fuel from the secondary loop. Also, a nominal 2 gallons of fuel was flushed from the secondary loop. This larger quantity was required because the secondary loop contained 2 fuel filters which comprised a large portion of the loop volume.

The order of the evaluation and a description of the testing as performed (and in accordance with the TCEQ-approved Test Plan) are given in Table 3. The only deviation from the approved test plan was the reduction in the number of engine maps performed after each fuel change where the number of maps was reduced from 4 to 2 in order to conserve fuel (Revision approved via email from Morris Brown of TCEQ – See Appendix B, Supporting Documents).

Table 3 Test history as specified in the Test Plan.

Day	Test Day Description
1	Laboratory Preparation & Calibration
2	TCEQ Runs: R R R C C C
3	TCEQ Runs: C C C R R R C C C R R R
4	TCEQ Runs: R R R C C C R R R C C C
5	TCEQ Runs: C C C R R R C C C R R R

R – Reference Fuel FTP, C – Candidate Fuel FTP

It is noted that a TCEQ-appointed observer, Mr. Clifford Tyree, was present during the entire testing period, from November 17, 2006 through November 21, 2006. Mr. Tyree was present for every hot start FTP run, candidate fuel preparation, and engine fuel changes.

Outliers / Blown Tests

During the test program, there were several tests that had to be excluded from the overall analysis due to observed data abnormalities and improper procedures. In the case of one test on the candidate fuel (E01534-02), the hydrocarbon analyzer 4-way valve, used to control the source of gas (probe, zero, span, bag) was mistakenly left in the zero position when it should have been switched to the probe/sample position. For test E01552-02 (Candidate fuel), the low-range carbon monoxide analyzer post-test span value drifted -6.5% (0.935) which exceeded the allowable span drift of ±2%. Data from test E01552-02 was saved but not used for the overall comparison while an additional hot start test (E01552-05) was run to obtain the third valid hot-start test for that sequence. During the last set of reference fuel tests (E01558) the oxides of nitrogen values, while not outliers, appeared to be lower then those from the previous reference fuel tests. After the third hot-start test of that sequence, an additional test was run since a sufficient quantity of fuel remained in the 16 gallon drum. In the final comparative analysis, data from E01558-02 was excluded from the analysis.

While not included in the comparative analysis, data from these tests are included in the QA/QC documentation. It was noted that emissions and performance data not affected by analyzer or operator errors were consistent with data from the tests used for the comparative analysis.

Reference Map for First Candidate Fuel Test Sequence

During a review of the data, it was found that an incorrect engine map was used to generate the FTP speed-torque schedule for the first sequence of candidate fuel tests. The software which generates the FTP speed-torque schedule does so using a map file located in a specific location on the computer hard drive. This map file is generated each time the engine is mapped and, prior to running FTP tests, the reference map generated immediately prior to the first reference fuel test sequence must be manually copied to that location on the hard drive. The test engineer mistakenly copied an incorrect map to that location resulting in the use of an incorrect FTP speed-time schedule for the first sequence of candidate fuel tests.

Upon investigation, it was determined that the map used to generate the incorrect FTP schedule was from a reference fuel map that had been generated previous to the map used for the all of the other comparative testing. The average engine work from the first sequence of three candidate fuel tests (E01534-02,

E01534-03, E01534-04) was 24.15 bhp-hr was 0.9% lower than that of the other 18 candidate fuel test runs (24.36 bhp-hr). Figure 2 and Figure 3 show, respectively, the engine power recorded during FTP runs on candidate fuel using torque-speed schedules generated from both correct and incorrect reference fuel maps. A comparative review of emissions and performance data from the candidate fuel test run using the incorrect map with those run using the correct map did not show any significant differences and the deviation in actual work was deemed small enough such that the first three candidate fuel runs could be included in the comparative data set.

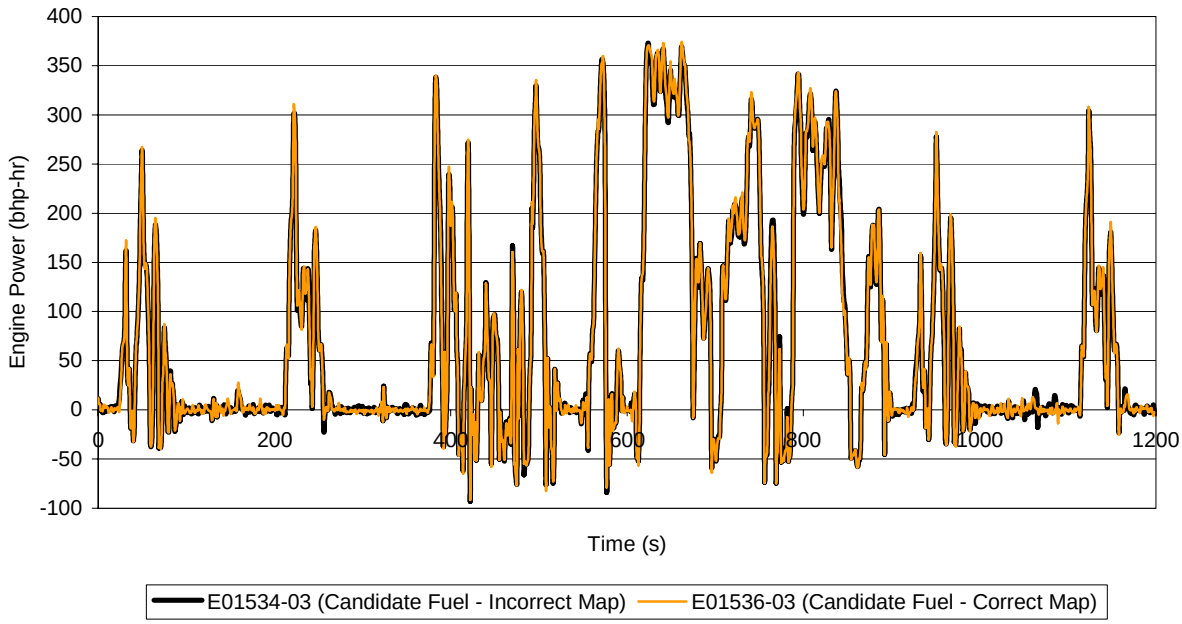

Figure 2: Engine power from test runs on candidate fuel using FTP schedule generated using both the correct reference fuel map and the incorrect reference fuel map.

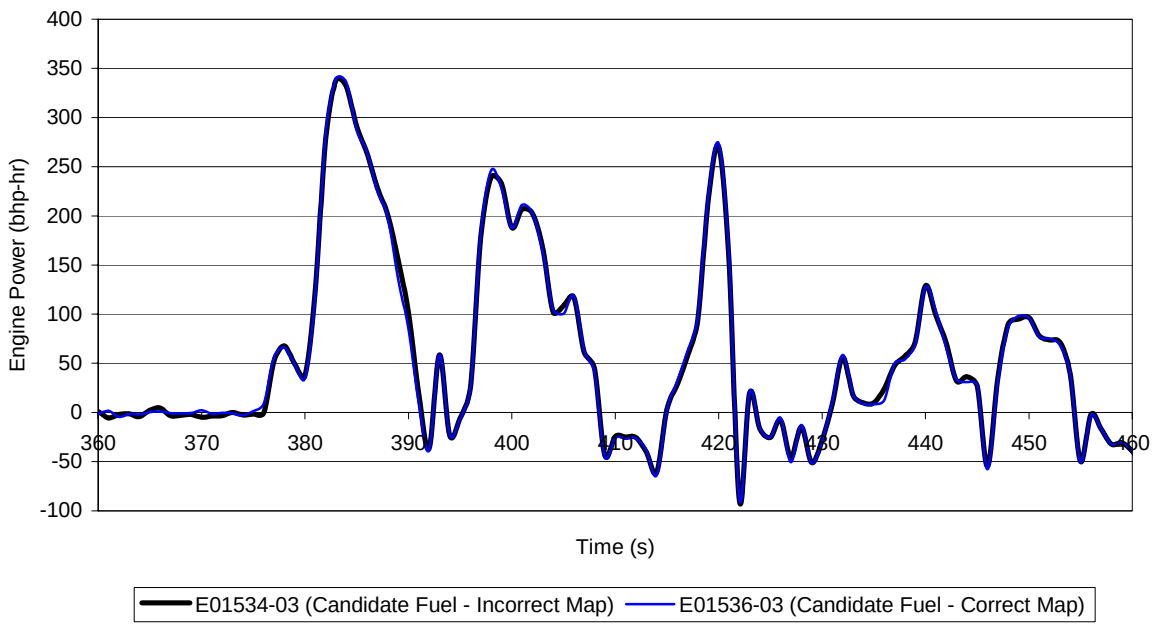

Figure 3: Detailed section of Figure 2.

Results

The emissions results for the evaluation are summarized in Table 4 while the outlier identification is presented in Table 5. It is noted that the CO data were not required but are reported here. A complete test

record containing laboratory calibration records, daily test log sheets, engine reference fuel mapping parameters, and individual test records (log, results, FTP validation data) has been submitted separately to TCEQ and to Clifford Tyree as part of WVU quality audit. Table 6 contains a cross reference of WVU Test Id numbers with the reference and candidate ID numbers used in the data tables and figures.

Table 4: Emissions results from all reportable test runs

	NOX		THC		TPM		NMHC		CO2		CO	
Test #	**REF**	**CAND**	**REF**	**CAND**	**REF**	**CAND**	**REF**	**CAND**	**REF**	**CAND**	**REF**	**CAND**
1	4.720	4.725	0.112	0.091	0.239	0.175	0.1074	0.0861	529.3	532.1	3.24	2.67
2	4.730	4.732	0.116	0.093	0.235	0.178	0.1114	0.0881	528.9	531.8	3.17	2.65
3	4.726	4.697	0.123	0.100	0.239	0.177	0.1184	0.0950	528.1	530.3	3.20	2.65
4	4.713	4.705	0.122	0.096	0.235	0.186	0.1170	0.0881	530.2	536.2	3.13	2.71
5	4.715	4.709	0.117	0.095	0.239	0.184	0.1118	0.0883	530.4	532.8	3.20	2.67
6	4.707	4.682	0.121	0.096	0.233	0.183	0.1160	0.0891	529.0	532.2	3.17	2.67
7	4.752	4.740	0.110	0.102	0.235	0.190	0.1049	0.0975	530.2	533.1	3.15	2.74
8	4.741	4.734	0.117	0.094	0.244	0.186	0.1120	0.0896	531.1	531.8	3.14	2.73
9	4.774	4.714	0.109	0.105	0.223	0.191	0.1047	0.1003	530.3	531.3	3.12	2.71
10	4.737	4.673	0.119	0.099	0.243	0.188	0.1136	0.0942	532.3	532.8	3.17	2.71
11	4.760	4.732	0.121	0.096	0.244	0.179	0.1158	0.0915	532.0	532.4	3.17	2.60
12	4.748	4.718	0.115	0.094	0.241	0.177	0.1100	0.0890	532.0	532.0	3.14	2.57
13	4.740	4.707	0.111	0.086	0.231	0.177	0.1059	0.0809	532.4	532.9	3.09	2.62
14	4.732	4.703	0.114	0.092	0.236	0.190	0.1092	0.0869	531.3	534.5	3.09	2.70
15	4.720	4.743	0.115	0.093	0.237	0.182	0.1100	0.0874	531.2	535.8	3.11	2.65
16	4.703	4.704	0.103	0.096	0.237	0.185	0.0982	0.0903	531.8	539.4	3.12	2.62
17	4.717	4.727	0.110	0.090	0.235	0.180	0.1046	0.0849	532.5	535.2	3.13	2.60
18	4.683	4.712	0.115	0.087	0.243	0.182	0.1098	0.0817	533.5	532.9	3.21	2.58
19	4.704	4.712	0.106	0.087	0.230	0.182	0.1013	0.0817	532.2	532.9	3.08	2.58
20	4.682	4.727	0.107	0.094	0.233	0.185	0.1022	0.0894	531.4	534.2	3.13	2.62
21	4.678	4.646	0.111	0.090	0.235	0.182	0.1056	0.0852	530.9	533.9	3.10	2.62
Average	**4.723**	**4.712**	**0.114**	**0.094**	**0.237**	**0.183**	**0.1090**	**0.0888**	**531.0**	**533.4**	**3.15**	**2.65**
COV	0.54%	0.50%	4.81%	5.14%	2.18%	2.55%	5.01%	5.59%	0.26%	0.38%	1.35%	1.96%

Table 5: Outlier criteria as determined using the methodology described in methodology employed in ASTM E178-02 (2002), Section 6

	NOX		THC		TPM		NMHC		CO2		CO	
	REF	CAND	REF	CAND	REF	CAND	REF	CAND	REF	CAND	REF	CAND
Count	21	21	21	21	21	21	21	21	21	21	21	21
MAX	4.774	4.743	0.123	0.105	0.244	0.191	0.118	0.100	533.491	539.426	3.239	2.741
Min	4.678	4.646	0.103	0.086	0.223	0.175	0.098	0.081	528.099	530.259	3.077	2.568
AVG	4.723	4.712	0.114	0.094	0.237	0.183	0.109	0.089	531.000	533.357	3.145	2.650
Std Dev	0.025	0.023	0.005	0.005	0.005	0.005	0.005	0.005	1.380	2.029	0.043	0.052
Max Outlier	OK	OK	OK	OK	OK	OK	OK	OK	OK	Outlier	OK	OK
Min Outlier	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Table 6: Test number cross reference

Reference Test #	WVU Test Id #	Candidate Test #	WVU Test Id #
1	E01532-02	1	E01534-03
2	E01532-03	2	E01534-04
3	E01532-04	3	E01534-05
4	E01538-02	4	E01536-02
5	E01538-03	5	E01536-03
6	E01538-04	6	E01536-04
7	E01542-02	7	E01540-02
8	E01542-03	8	E01540-03
9	E01542-04	9	E01540-04
10	E01544-02	10	E01546-02
11	E01544-03	11	E01546-03
12	E01544-04	12	E01546-04
13	E01548-02	13	E01550-02
14	E01548-03	14	E01550-03
15	E01548-04	15	E01550-04
16	E01554-02	16	E01552-03
17	E01554-03	17	E01552-04
18	E01554-04	18	E01552-05
19	E01558-03	19	E01556-03
20	E01558-04	20	E01556-04
21	E01558-05	21	E01556-05

Figure 4 and Figure 5 show the oxides of nitrogen emissions, respectively, from the reference and candidate fuels. The average NOx emissions from the reference fuel were 4.723 g/bhp-hr while those from the candidate fuel were 4.714 g/bhp-hr.

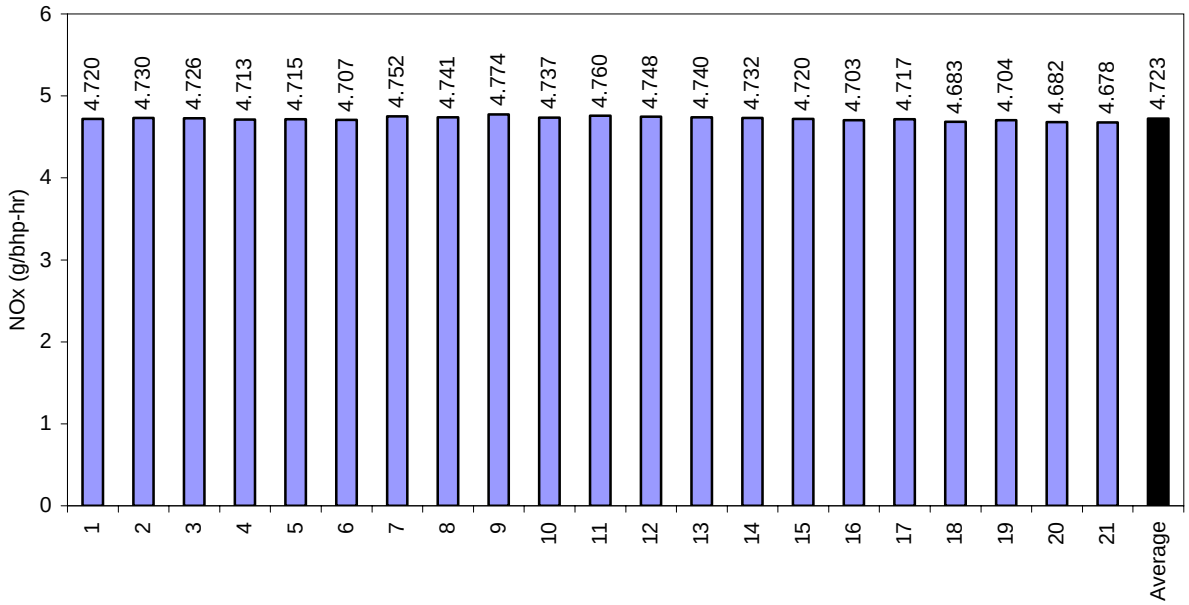

Figure 4: Oxides of Nitrogen emissions from reference fuel tests.

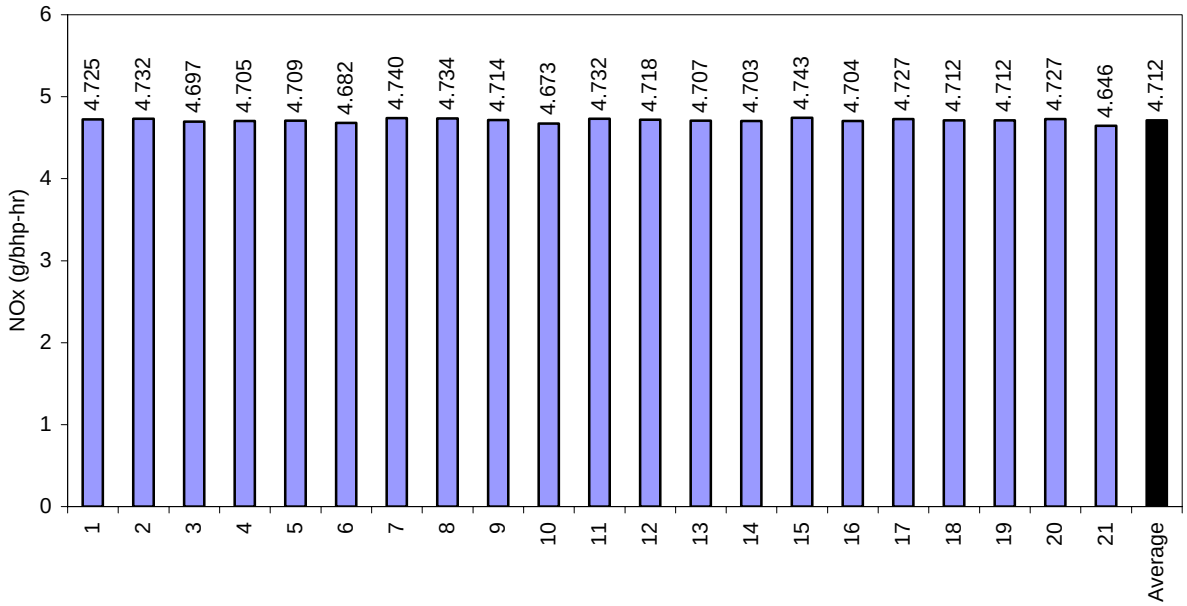

Figure 5: Oxides of Nitrogen emissions from candidate fuel tests.

Figure 6 and Figure 7 show total hydrocarbon emissions, respectively, from the reference and candidate fuel tests. The average total hydrocarbon emissions from the candidate fuel tests (0.094 g/bhp-hr) were 17.5% lower than that from the reference fuel (0.114 g/bhp-hr).

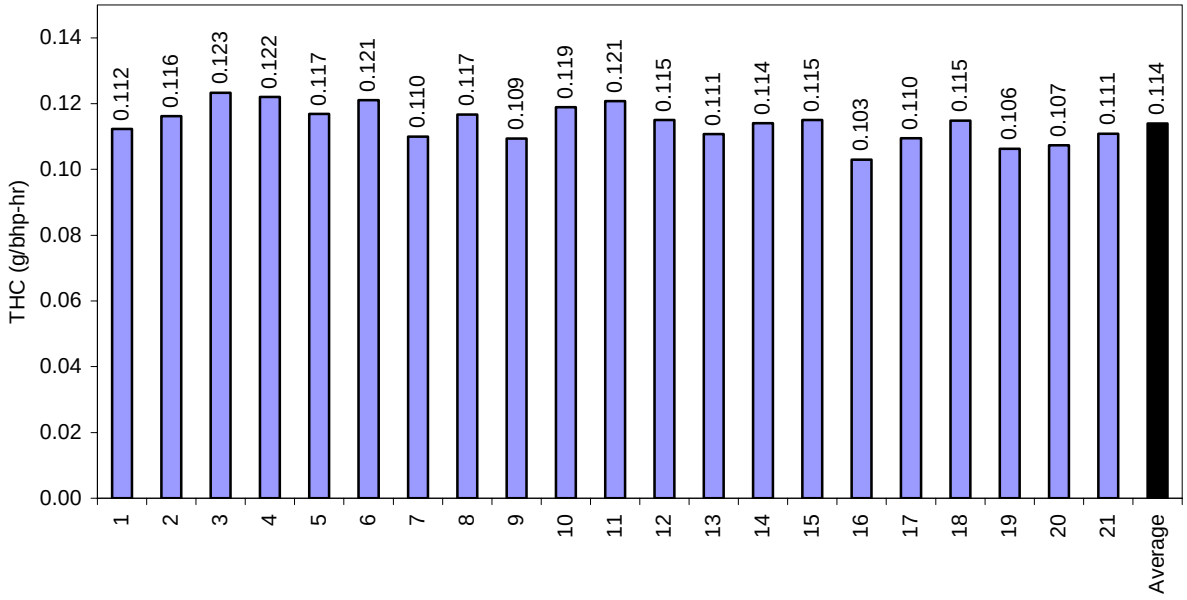

Figure 6: Total Hydrocarbon emissions from reference fuel tests.

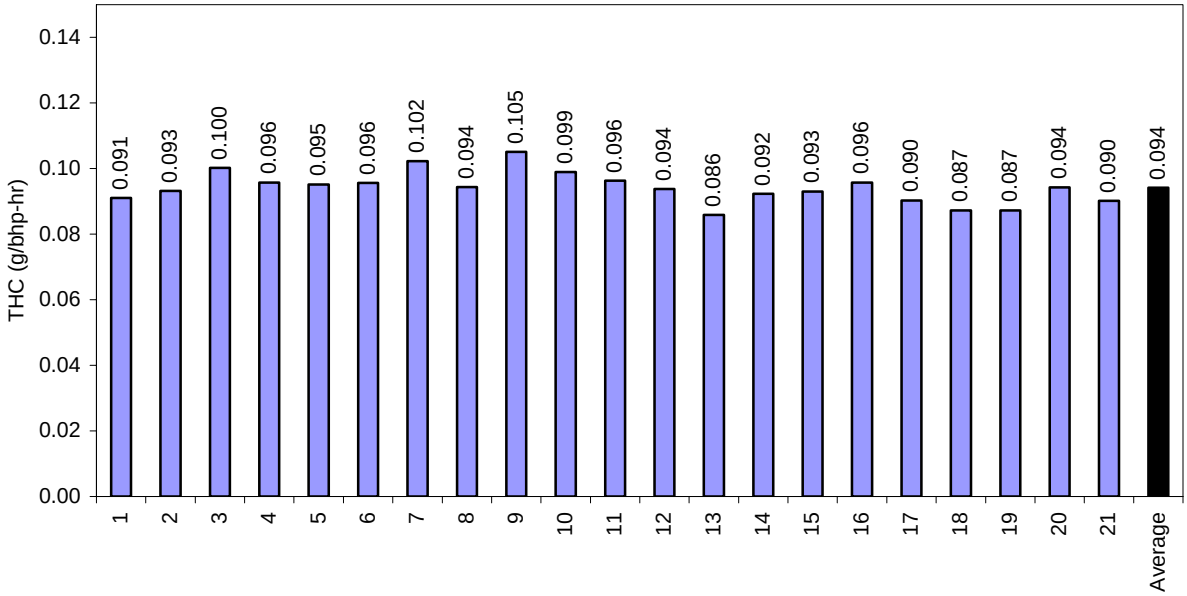

Figure 7: Total Hydrocarbon emissions from candidate fuel tests.

Figure 8 and Figure 9 show, respectively, the non-methane hydrocarbon emissions from the reference and candidate fuel tests. The average non-methane hydrocarbon emissions from the candidate fuel (0.0888 g/bhp-hr) were 18.7% lower than that from the reference fuel (0.1092 g/bhp-hr). This difference was comparable to the difference in total hydrocarbon emissions between the reference and candidate fuels (17.5%).

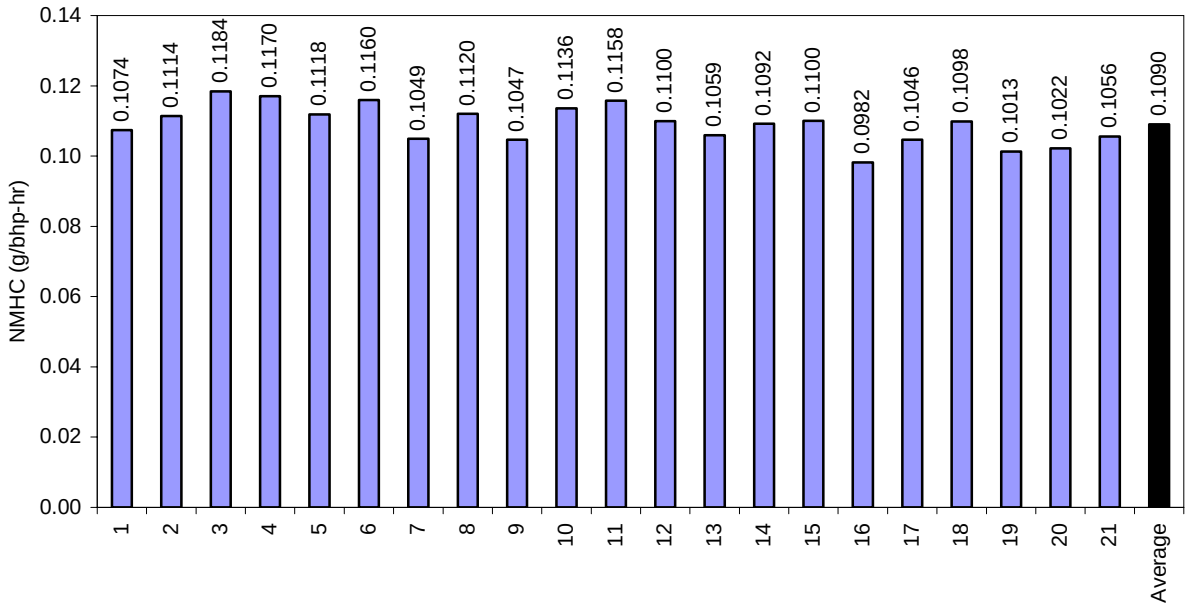

Figure 8: Non-Methane Hydrocarbon emission from the reference fuel tests.

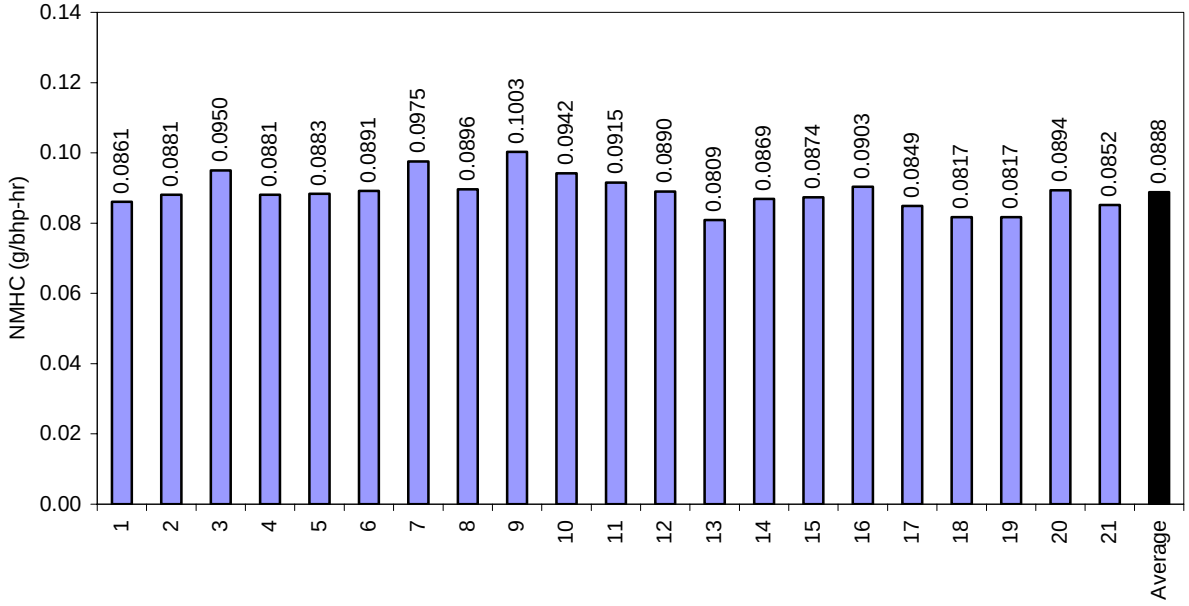

Figure 9: Non-Methane Hydrocarbon emissions from the candidate fuel tests.

Figure 10 and Figure 11 show, respectively, the total particulate matter emissions from the reference and candidate fuel tests. The average total particulate matter emissions from the candidate fuel (0.183 g/bhp-hr) was 22.8% lower than that from the reference fuel (0.237 g/bhp-hr). This difference is typical of what WVU has observed when testing other B20 blends.

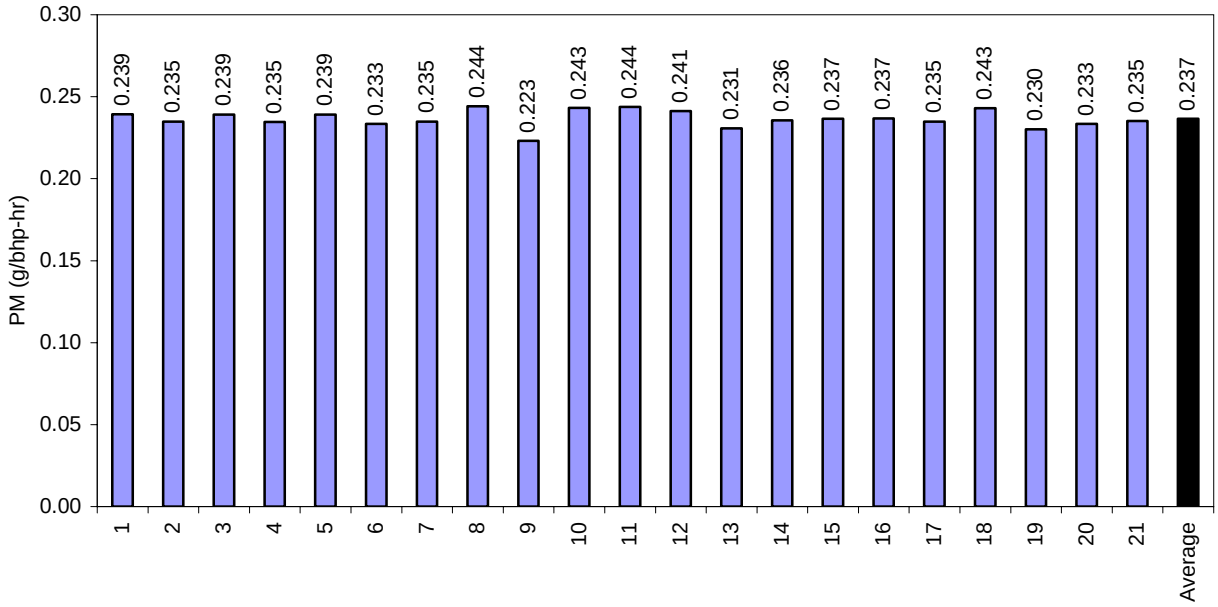

Figure 10: Total particulate matter emissions from the reference fuel tests.

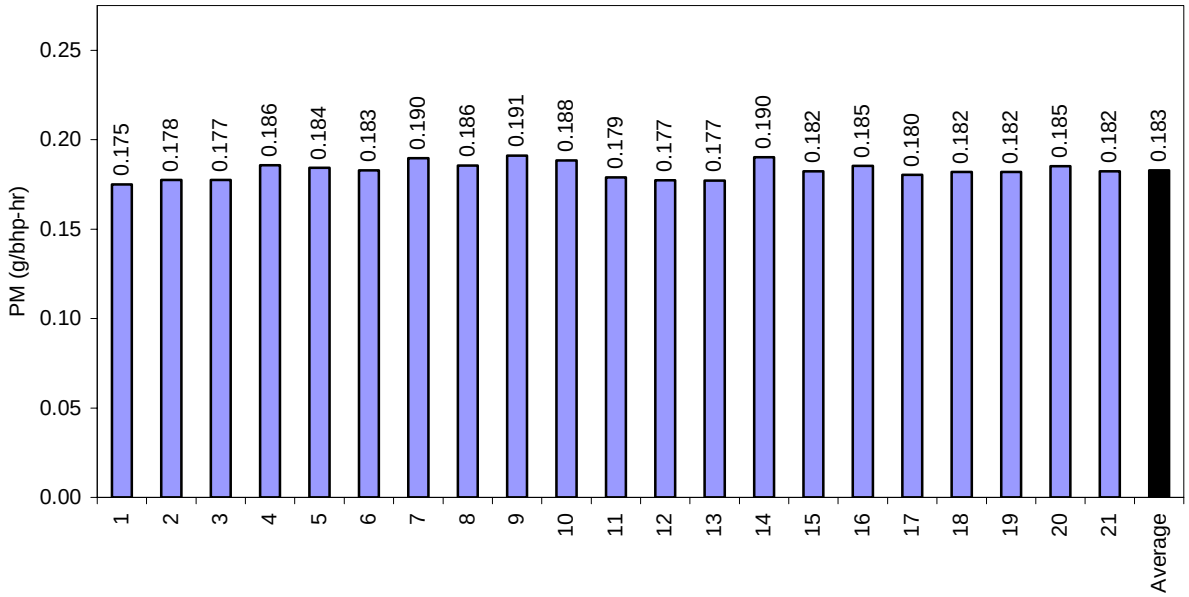

Figure 11: Total particulate matter emissions from the candidate fuel tests.

Figure 12 and Figure 13 show, respectively, the carbon dioxide emissions from the reference and candidate fuel tests. The average carbon dioxide emissions from the candidate fuel tests were 0.6% higher than that from the reference fuel.

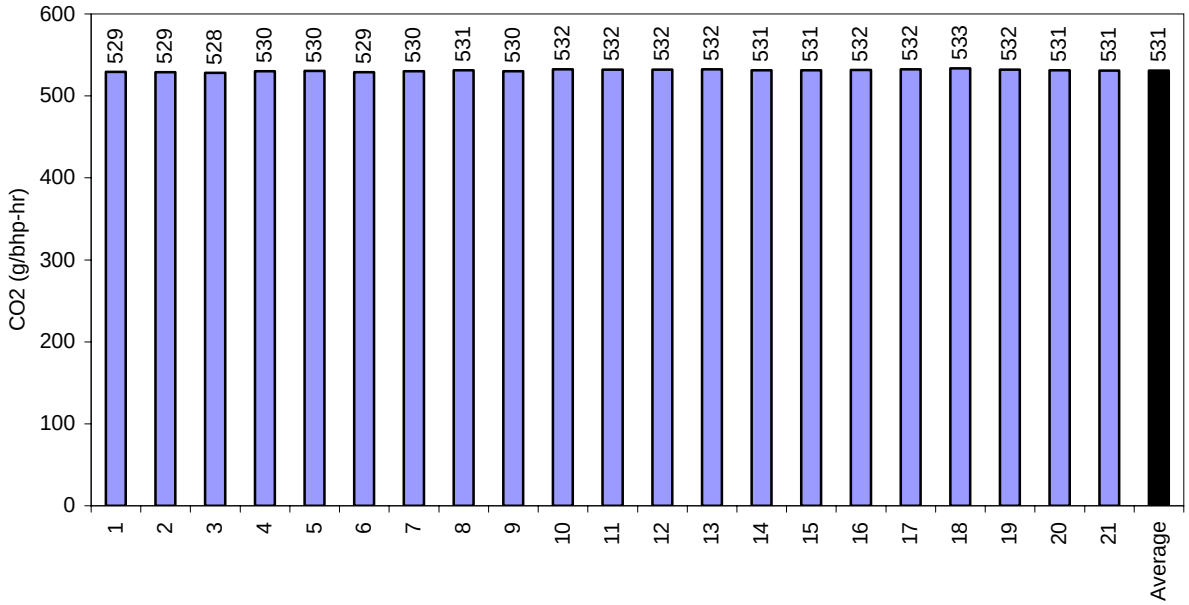

Figure 12: Carbon dioxide emissions from the reference fuel tests.

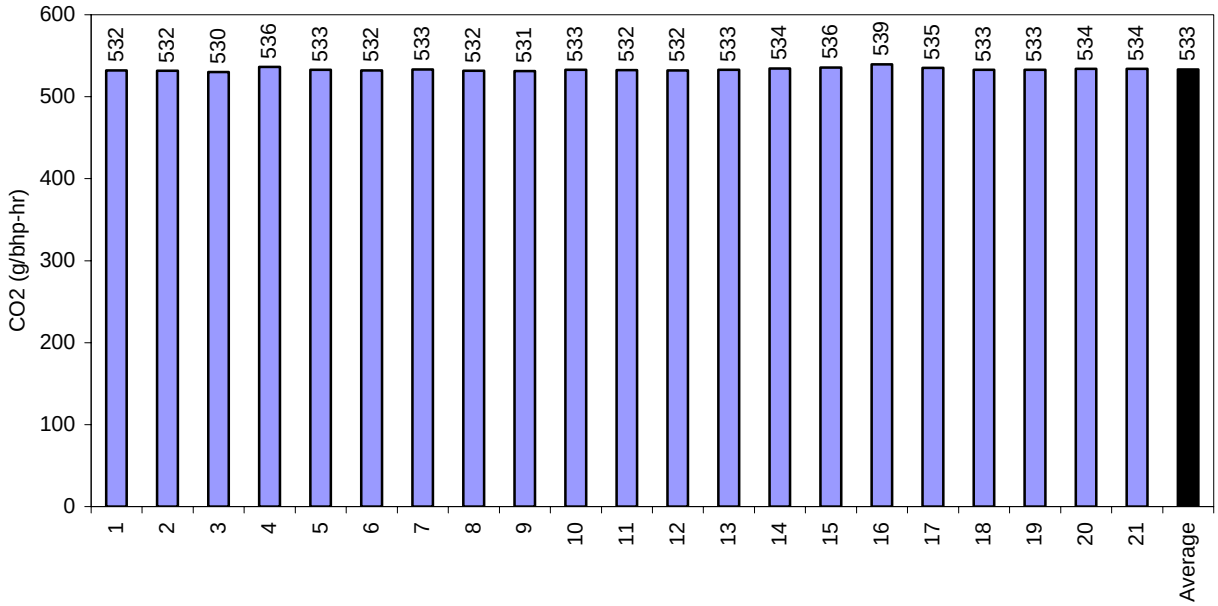

Figure 13: Carbon dioxide emissions from the candidate fuel tests.

Figure 14 and Figure 15 show, respectively, carbon monoxide emissions from the reference and candidate fuel tests. The average carbon monoxide emissions from the candidate fuel tests (2.65 g/bhp-hr) was 15.9% lower than that from the reference fuel tests (3.15 g/bhp-hr). Carbon monoxide is not a regulated emission.

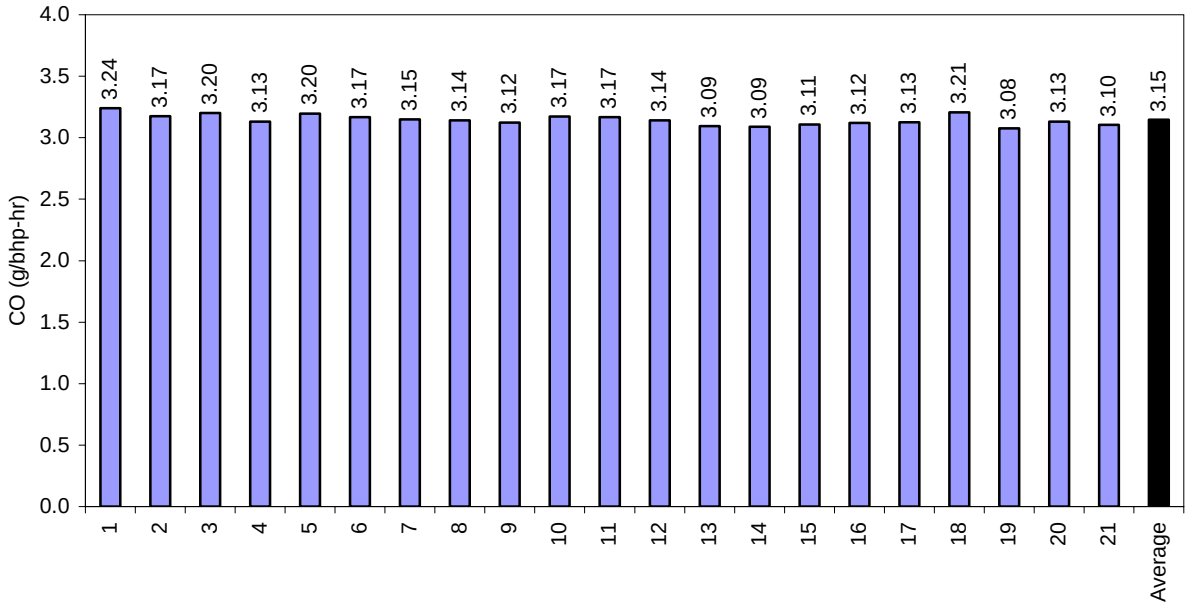

Figure 14: Carbon monoxide emissions from the reference fuel tests.

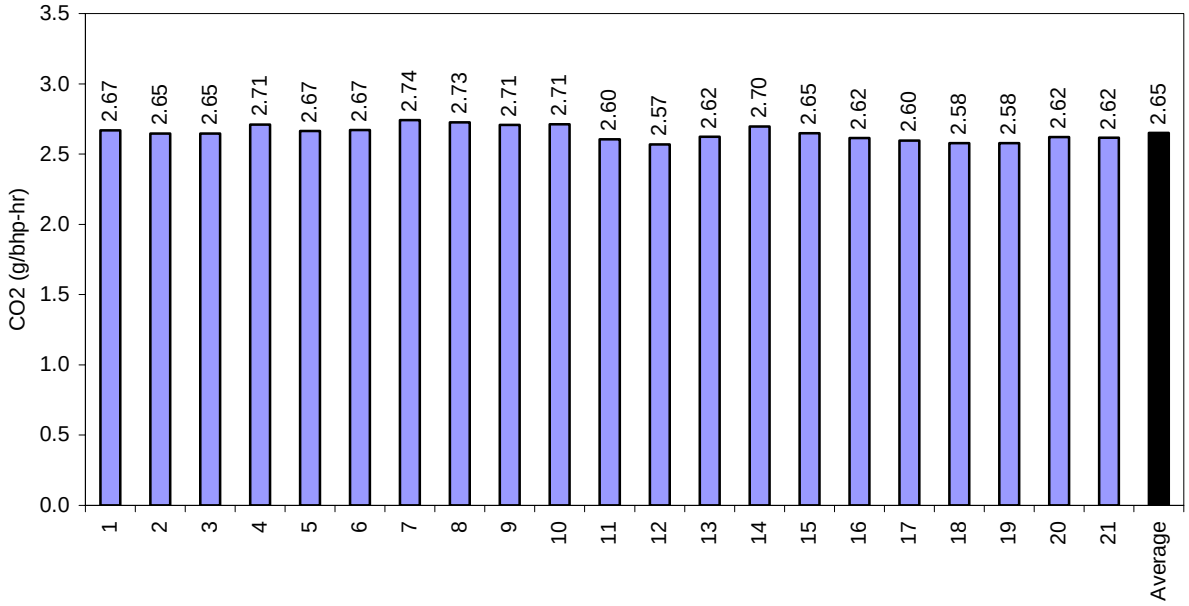

Figure 15: Carbon monoxide emissions from the candidate fuel tests.

Figure 16 and Figure 17 show, respectively, the brake specific fuel consumption from the reference and candidate fuel tests. The average brake specific fuel consumption for the candidate fuel tests (0.389 g/bhp-hr) was 2.6% higher than that from the reference fuel tests (0.379 g/bhp-hr). The relative increase in brake specific fuel consumption for the candidate fuel can be attributed to its slightly lower energy content and the presence of oxygen (as part of the biodiesel esters) as compared to the reference fuel.

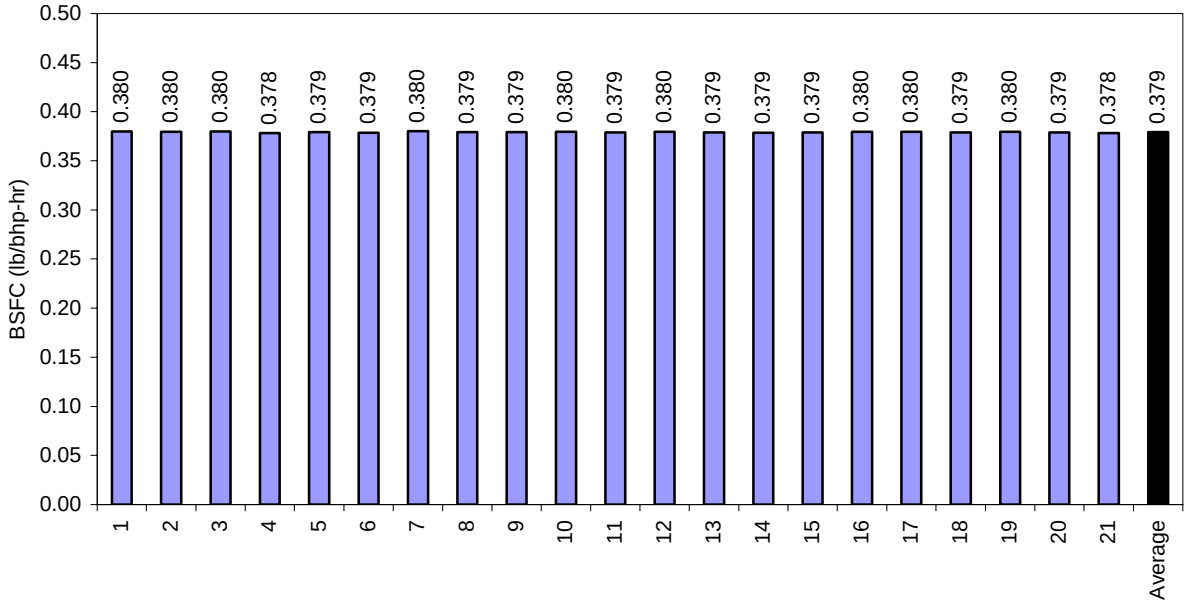

Figure 16: Brake specific fuel consumption for the reference fuel tests.

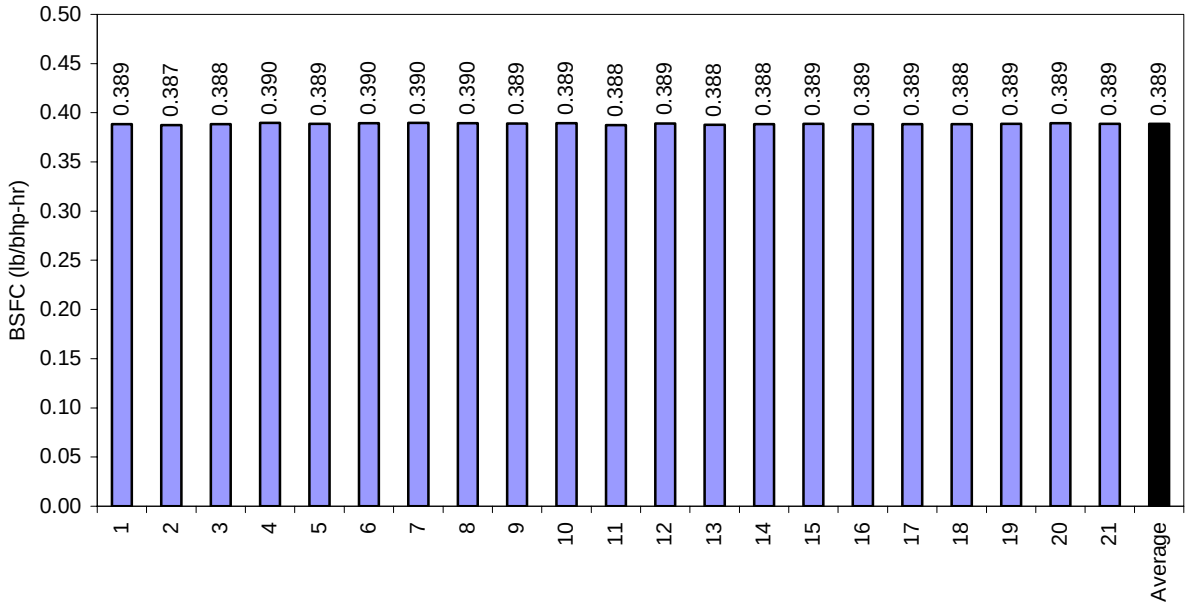

Figure 17: Brake specific fuel consumption for the candidate fuel tests.

Candidate Fuel Emissions Passage Criteria

The average emission level of the Candidate fuel treated was compared to the average emission level of the Reference fuel using the one-sided Student's t statistics shown in Equation (1).

$$\overline{X}_C \le \overline{X}_R + \delta - S_P \sqrt{2/n}\, t(a, 2n-2) \qquad (1)$$

Rewriting the right hand side (RHS) as Equation (2).

$$RHS = \overline{X}_R + \delta - S_P \sqrt{2/n}\, t(a, 2n-2) \qquad (2)$$

The Candidate fuel must satisfy Equation (3)

$$\overline{X}_C \le RHS. \qquad (3)$$

In accordance with TAC §114.315(c)(5), the tolerance level, δ, pooled standard deviation, S_P, and Student's t statistics are given in the Table 7. The calculations presented in Table 7 are based on the recommended procedure by the TCEQ. As shown in this table, all of the tested pollutants as defined in TAC §114.315(c)(4)(E), namely NOx, THC, NMHC, and TPM, for the Candidate fuel were less than those of the Reference fuel when using the one-sided Student's t test and hence pass the criteria for each pollutant.

Table 7: Student's t statistical analysis of results

	Average X_C (g/bhp-hr)	Average X_R (g/bhp-hr)	δ (%)	Nc (-)	Nr (-)	n (-)	S_P (g/bhp-hr)	Sqr[2/n] (-)	df (-)	t(2*.15,df) (-)	RHS (g/bhp-hr)	Satisfy Criteria?
THC	0.0941	0.1142	2	21	21	42	0.00081	0.2182	82	1.0430	0.116	Yes
NMHC	0.0885	0.1092	2	21	21	42	0.00081	0.2182	82	1.0430	0.111	Yes
NOx	4.714	4.723	1	21	21	42	0.00354	0.2182	82	1.0430	4.769	Yes
TPM	0.183	0.237	2	21	21	42	0.00077	0.2182	82	1.0430	0.241	Yes

Conclusions

A Candidate diesel fuel prepared by mixing 20% (by volume) with 80% (by volume) TxLED reference fuel with 0.125% (by volume) 2 ethyl-hexyl nitrate will produce comparable or lower emissions than that of the TxLED fuel alone. Additionally, the Candidate fuel will produce comparable integrated work and BSFC values to that produced by the TxLED reference fuel.

References

1 *Title 40 Code of Federal Regulations, Part 86*, U.S. Government Printing Office, Washington, DC, 2000.

2 *Methane Measurement Using Gas Chromatograph*, Society of Automotive Engineers, Recommended Practice SAE J1151, Warrendale, PA, 1991.

Appendix A – Fuel Analyses

Envirodiesel® blend stock analysis

INSPECTORATE
ISO 9001-2000 Certified

Certificate of Analysis

Laboratory Submission No. 2006-HTC-11318

Sample Submitted By : World Energy
Client Reference :
Vessel :
Terminal / Port / Office : World Energy
Analysis Performed By : Houston Technical Center

Sample ID : 2006-HTC-11318-001
Customer Product Description : QC: T10011 (WV) 11/14/06 15:00 Bio Diesel
Date Sampled : 15-Nov-06

				Specifications	
Method	Test	Result	Unit	Min.	Max.
ASTM D1160	AET at IBP	324	°C		
ASTM D1160	AET at 5% Recovered	345	°C		
ASTM D1160	AET at 10% Recovered	346	°C		
ASTM D1160	AET at 20% Recovered	347	°C		
ASTM D1160	AET at 30% Recovered	347	°C		
ASTM D1160	AET at 40% Recovered	348	°C		
ASTM D1160	AET at 50% Recovered	350	°C		
ASTM D1160	AET at 60% Recovered	351	°C		
ASTM D1160	AET at 70% Recovered	352	°C		
ASTM D1160	AET at 80% Recovered	354	°C		
ASTM D1160	AET at 90% Recovered	356	°C		360
ASTM D1160	AET at 95% Recovered	359	°C		
ASTM D1160	AET at EP	399	°C		
ASTM D1160	Recovery	99.0	Vol %		
ASTM D1160	Residue	1.0	Vol %		
ASTM D1160	Cold Trap Recovery	0.0	Vol %		
ASTM D1160	Loss	0.0	Vol %		
ASTM D130 (IP 154)	Corrosion Copper Strip at 50°C (122°	1a			3
ASTM D2500 (IP 219)	Cloud Point	9	°C		Report
ASTM D2500 (IP 219)	Cloud Point	48	°F		Report
ASTM D2709	Water and Sediment	0.000	% (V/V)		0.050
ASTM D445 (IP 71)	Test Temperature	40°C (104°F)			
ASTM D445 (IP 71)	Kinematic Viscosity	4.350	cSt	1.9	6.0
ASTM D4530 Mod. B	Carbon Residue	<0.05	% (m/m)		0.050
ASTM D4951	Phosphorus	<0.001	Mass %		0.001
ASTM D5453	Sulfur Content	9.5	ppm (mg/kg)		10
ASTM D613 Ran by Outside Lab	Cetane Number	57.1		47	

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Envirodiesel® blend stock analysis (cont.)

INSPECTORATE
ISO 9001-2000 Certified

Certificate of Analysis

Sample ID : 2006-HTC-11318-001
Customer Product Description : QC: T10011 (WV) 11/14/06 15:00 Bio Diesel
Date Sampled : 15-Nov-06

Method	Test	Result	Unit	Specifications Min.	Specifications Max.
ASTM D6584	Free Glycerin	0.012	Mass %		0.020
ASTM D6584	Total Glycerin	0.119	Mass %		0.240
ASTM D6584	Monoglyceride Content	0.387	Mass %		
ASTM D6584	Diglyceride Content	0.046	Mass %		
ASTM D6584	Triglyceride Content	<0.005	Mass %		
ASTM D664 (IP 177)	Total Acid Number	0.10	mg KOH/g		0.50
ASTM D874 (IP 163)	Ash Content	<0.005	Mass %		0.020
ASTM D93 (IP 34) Procedure A	Flash Point	>130	°C	130.0	
UOP 389	Calcium	0.54	mg/kg		
UOP 389	Magnesium	<0.02	mg/kg		
UOP 389	Calcium + Magnesium	0.54	mg/kg		5.0
UOP 391	Sodium	1.3	mg/kg		
UOP 391	Potassium	<0.1	mg/kg		
UOP 391	Sodium + Potassium	1.3	mg/kg		5.0

Manager Approval: Jesse Diaz

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Envirodiesel® blend stock analysis (cont.)

INSPECTORATE
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Certificate of Analysis

Laboratory Submission No. 2006-HTC-11318

Method Modification	Modification Description
Mod. A	Analysis to be performed on product not specified by the method
Mod. B	Result to be reported outside of the reporting range of the method
Mod. C	Modification in the procedure of the method
Mod. D	Result reported with a different unit than prescribed in the method
Mod. E	Result reported with a different precision than prescribed in the method
Mod. F	Modification to instrument or calibration procedure prescribed by the method

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Candidate Fuel Analysis (note: 2EHN additive not present in sample)

SAYBOLT LP
21730 S. Wilmington Avenue
Suite 201
Carson, CA 90810
310-518-4400 Telephone
310-518-4455 Facsimile

Fast To The Point

Saybolt LP

Certificate of Analysis

WEST VIRGINIA UNIVERSITY
MAE DEPT \ PO BOX 6106
MORGANTOWN, WV 26505
David McKain

		Date Sampled:	10/13/2006
Report Date:	10/27/2006	Product:	Bio-Diesel Blend
Job No:	13091-00003007	Location:	Morgantown, WV
Sample Number:	601880-01	Sample ID:	(1of3) World Energy B-20 Mix 2 WVFuel0737
Client Ref:	World Energy	Vessel:	

Test	Method	Result	Units
Free Water & Particulates (Appearance)			
Visual Inspection	ASTM D- 4176	C & B	
Vortex Inspection	ASTM D- 4176	Pass	Pass/ Fail
Aromatics by Supercritical Fluid Chromatography			
Monoaromatics	ASTM D-5186	8.4	wt%
Polynuclear Aromatics		1.4	wt%
Total Aromatics		9.8	wt%
Aromatics by Supercritical Fluid Chromatography			
Total Aromatics	D-5186	10.3	lv%
Carbon Residue-Rams.(10 % Resid	ASTM D-524 D86	0.03	wt%
Gravity, API @ 60 °F	ASTM D-1298	37.0	@ 60 °F
Flash Point, Pensky Martens	ASTM D-93A	156	°F
IBP	ASTM D-86	376.4	
10% Rec		437.9	
50% Rec		540.1	
90% Rec		632.8	
End Point		658.9	
Recovery		97.8	
Residue		1.4	
Loss		0.8	
Cloud Point	ASTM D-2500	12	°F
Corrosion, 3 hrs @ 122°F	ASTM D-130	1a	
Cetane Number, Ignition Quality	ASTM D-613	50.8	
Cetane Index	ASTM D-976	53.6	
Ash	ASTM D-482	<0.01	Wt%

Issuer warrants that it has exercised due diligence and care with respect to the information and professional judgments embodied in this report. This report reflects only the findings at the time and place of inspection and testing. Issuer expressly disclaims any further indemnity of any kind. This report is not a guarantee or policy of insurance with respect to the goods or the contractual performance of any party. Any person relying upon this report should be aware that issuer's activities are carried out under their general terms and conditions.

"Precision parameters apply in the evaluation of the test results specified above. Please also refer to ASTM D 3244 (except for analysis of RFG), IP 367 and appendix E of IP standard methods for analysis testing with respect to the utilization of test data to determine conformance with specifications"

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		Date Sampled:	10/13/2006
Report Date:	10/27/2006	Product:	Bio-Diesel Blend
Job No:	13091-00003007	Location:	Morgantown, WV
Sample Number:	601880-01	Sample ID:	(1of3) World Energy B-20 Mix 2 WVFuel0737
Client Ref:	World Energy	Vessel:	

Test	Method	Result	Units
Kinematic Viscosity @ 40 deg. C	ASTM D-445	3.24	cSt
Nitrogen, Total	ASTM D-4629	6	ppm wt
Sediment & Water	ASTM D-2709	0.0	lv%
Total Sulfur	ASTM D-5453	11.05	ppm wt

Approved By: Signature On File
Ken Nabi
Laboratory Manager

Issuer warrants that it has exercised due diligence and care with respect to the information and professional judgments embodied in this report. This report reflects only the findings at the time and place of inspection and testing. Issuer expressly disclaims any further indemnity of any kind. This report is not a guarantee or policy of insurance with respect to the goods or the contractual performance of any party. Any person relying upon this report should be aware that issuer's activities are carried out under their general terms and conditions.

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David McKain

		Date Sampled:	10/13/2006
Report Date:	10/27/2006	Product:	Bio-Diesel Blend
Job No:	13091-00003007	Location:	Morgantown, WV
Sample Number:	601880-02	Sample ID:	(2of3) World Energy B-20 Mix 2 WVFuel0738
Client Ref:	World Energy	Vessel:	

Test	Method	Result	Units
Free Water & Particulates (Appearance)			
Visual Inspection	ASTM D- 4176	C & B	
Vortex Inspection	ASTM D- 4176	Pass	Pass/ Fail
Aromatics by Supercritical Fluid Chromatography			
Monoaromatics	ASTM D-5186	8.4	wt%
Polynuclear Aromatics		1.4	wt%
Total Aromatics		9.8	wt%
Aromatics by Supercritical Fluid Chromatography			
Total Aromatics	D-5186	10.3	lv%
Carbon Residue-Rams.(10 % Resid	ASTM D-524 D86	0.04	wt%
Gravity, API @ 60 °F	ASTM D-1298	37.0	@ 60 °F
Flash Point, Pensky Martens	ASTM D-93A	158	°F
IBP	ASTM D-86	370.0	
10% Rec		433.5	
50% Rec		539.4	
90% Rec		633.7	
End Point		658.9	
Recovery		97.1	
Residue		1.4	
Loss		1.5	
Cloud Point	ASTM D-2500	8	°F
Corrosion, 3 hrs @ 122°F	ASTM D-130	1a	
Cetane Number, Ignition Quality	ASTM D-613	51.9	
Cetane Index	ASTM D-976	53.5	
Ash	ASTM D-482	<0.01	Wt%

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Candidate Fuel Analysis (cont.)

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Report Date:	10/27/2006	Product:	Bio-Diesel Blend
Job No:	13091-00003007	Location:	Morgantown, WV
Sample Number:	601880-02	Sample ID:	(2of3) World Energy B-20 Mix 2 WVFuel0738
Client Ref:	World Energy	Vessel:	

Test	Method	Result	Units
Kinematic Viscosity @ 40 deg. C	ASTM D-445	3.13	cSt
Nitrogen, Total	ASTM D-4629	6	ppm wt
Sediment & Water	ASTM D-2709	0.0	lv%
Total Sulfur	ASTM D-5453	10.68	ppm wt

Approved By: Signature On File
Ken Nabi
Laboratory Manager

Issuer warrants that it has exercised due diligence and care with respect to the information and professional judgments embodied in this report. This report reflects only the findings at the time and place of inspection and testing. Issuer expressly disclaims any further indemnity of any kind. This report is not a guarantee or policy of insurance with respect to the goods or the contractual performance of any party. Any person relying upon this report should be aware that issuer's activities are carried out under their general terms and conditions.

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Page 4 of 6

Candidate Fuel Analysis (cont.)

SAYBOLT LP
21730 S. Wilmington Avenue
Suite 201
Carson, CA 90810
310-518-4400 Telephone
310-518-4455 Facsimile

Fast To The Point

Saybolt LP

Certificate of Analysis

WEST VIRGINIA UNIVERSITY
MAE DEPT \ PO BOX 6106
MORGANTOWN, WV 26505
David McKain

		Date Sampled:	10/13/2006
Report Date:	10/27/2006	Product:	Bio-Diesel Blend
Job No:	13091-00003007	Location:	Morgantown, WV
Sample Number:	601880-03	Sample ID:	(3of3) World Energy B-20 Mix 2 WVFuel07397
Client Ref:	World Energy	Vessel:	

Test	Method	Result	Units
Free Water & Particulates (Appearance)			
Visual Inspection	ASTM D- 4176	C & B	
Vortex Inspection	ASTM D- 4176	Pass	Pass/ Fail
Aromatics by Supercritical Fluid Chromatography			
Monoaromatics	ASTM D-5186	8.4	wt%
Polynuclear Aromatics		1.4	wt%
Total Aromatics		9.8	wt%
Aromatics by Supercritical Fluid Chromatography			
Total Aromatics	D-5186	10.3	lv%
Carbon Residue-Rams.(10 % Resid	ASTM D-524 D86	0.05	wt%
Gravity, API @ 60 °F	ASTM D-1298	37.0	@ 60 °F
Flash Point, Pensky Martens	ASTM D-93A	158	°F
IBP	ASTM D-86	372.9	
10% Rec		434.4	
50% Rec		540.0	
90% Rec		633.2	
End Point		659.7	
Recovery		97.6	
Residue		1.3	
Loss		1.1	
Cloud Point	ASTM D-2500	8	°F
Corrosion, 3 hrs @ 122°F	ASTM D-130	1a	
Cetane Number, Ignition Quality	ASTM D-613	52.9	
Cetane Index	ASTM D-976	53.6	
Ash	ASTM D-482	<0.01	Wt%

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Page 5 of 6

Candidate Fuel Analysis (cont.)

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MAE DEPT \ PO BOX 6106
MORGANTOWN, WV 26505
David McKain

		Date Sampled:	10/13/2006
Report Date:	10/27/2006	Product:	Bio-Diesel Blend
Job No:	13091-00003007	Location:	Morgantown, WV
Sample Number:	601880-03	Sample ID:	(3of3) World Energy B-20 Mix 2 WVFuel07397
Client Ref:	World Energy	Vessel:	

Test	Method	Result	Units
Kinematic Viscosity @ 40 deg. C	ASTM D-445	3.13	cSt
Nitrogen, Total	ASTM D-4629	5	ppm wt
Sediment & Water	ASTM D-2709	0.0	lv%
Total Sulfur	ASTM D-5453	10.61	ppm wt

Approved By: Signature On File
Ken Nabi
Laboratory Manager

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Reference Fuel Analysis

06/26/2006 07:25 13105184455 SAYBOLT WEST COAST PAGE 01/02

Saybolt
A CORE LABORATORIES COMPANY

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Fast To The Point

Saybolt LP

Certificate of Analysis

WEST VIRGINIA UNIVERSITY
MAE DEPT \ PO BOX 6106
MORGANTOWN, WV 26505
David McKain

Report Date: 5/19/2006
Job No: 13091-00002422
Sample Number: 600843-01

Client Ref:

Date Sampled:
Product: Diesel
Location: Morgantown, WV
Sample ID: WVFuel0547 Tex - LED - 02, World Energy

Vessel:

Test	Method	Result	Units
API Gravity @ 60 Deg. F	ASTM D-287	38.9	deg.API
Aromatics by Supercritical Fluid Chromatography			
Monoaromatics	ASTM D-5186	8.26	wt%
Polynuclear Aromatics		0.91	wt%
Total Aromatics		9.17	wt%
Carbon/Hydrogen Content			
Carbon Content	ASTM D-5191M	85.81	wt%
Hydrogen Content		14.01	wt%
Cetane Number	ASTM D-613	49.3	
Distillation			
IBP	ASTM D-86	350.8	deg.F
5% Rec		391.3	deg.F
10% Rec		403.0	deg.F
20% Rec		428.9	deg.F
30% Rec		457.7	deg.F
40% Rec		487.3	deg.F
50% Rec		510.7	deg.F
60% Rec		527.3	deg.F
70% Rec		537.9	deg.F
80% Rec		547.8	deg.F
90% Rec		564.3	deg.F
95% Rec		594.4	deg.F
FBP		620.1	deg.F
Recovery		97.4	%
Residue		1.4	%
Loss		1.2	%

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Page 1 of 2

Reference Fuel Analysis (cont.)

06/26/2006 07:25 13105184455 SAYBOLT WEST COAST PAGE 02/02

SAYBOLT LP
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Fast To The Point

Saybolt LP

Saybolt
A CORE LABORATORIES COMPANY

Certificate of Analysis

WEST VIRGINIA UNIVERSITY
MAE DEPT \ PO BOX 6106
MORGANTOWN, WV 26505
David McKain

Report Date: 5/19/2006
Job No: 13091-00002422
Sample Number: 600843-01

Client Ref:

Date Sampled:
Product: Diesel
Location: Morgantown, WV
Sample ID: WVFuel0547 Tex - LED - 02, World Energy

Vessel:

Test	Method	Result	Units
Flash Point, PMCC	ASTM D-93(A)	152	deg.F
Kinematic Viscosity @ 40 deg. C	ASTM D-445	2.938	cSt
Nitrogen, Total	ASTM D-4629	1.0	ppm wt
Specific Gravity	ASTM D-1298	0.8304	@ 60 deg.F
Total Sulfur	ASTM D-5453	12.1	ppm wt

*Analysis results for D5291M are submitted by a third party laboratory. Saybolt was not present whilst the analysis was carried out, and has signed for receipt only with no liability accepted.

Approved By: Signature On File
Ken Nabi
Laboratory Manager

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Page 2 of 2

Appendix B – Supporting Documents

Email from Morris Brown in response to request to reduce number of engine maps between fuel changeovers from four (4) to two (2).

David,

Your request for a modification to the approved test protocol to reduce the number of engine maps between fuel switches is approved, with the following stipulations:

1. The final test report should document the change in procedure and the rationale for concluding that the change from the earlier triplicate, and subsequent single, maps would provide enough information to confirm the fuel change and associated mechanical adjustments did not alter the behavior of the engine.

2. If the fuel change and associated adjustments did alter the behavior of the engine, WVU would need to correct any problems and re-map at least once to confirm the engine map was (back) within spec.

Please call me at (512) 239-1438 if you have any questions.

Sincerely,

Morris R. Brown
Air Quality Division
Chief Engineer's Office
Texas Commission on Environmental Quality (TCEQ)
Mail Code: 204
P.O. Box 13087, Austin TX 78711-3087
Phone: (512) 239-1438
FAX: (512) 239-0077
Email: mbrown@tceq.state.tx.us

>>> "David McKain" <David.McKain@mail.wvu.edu> 11/20/2006 12:39 PM >>>

Morris,

I left a phone message for you but needed to follow up.

Our current test plan calls for 3 engine maps (full throttle through the entire engine speed range) when we switch fuel drums. This procedure is performed to confirm that the fuel change, which requires changing valve positions in the primary and secondary loops of the system, do not alter the behavior of the engine (e.g. valve left in wrong position causes lower torque values). Our belief is that this can be accomplished by performing a single (1) engine map after warming the engine after the fuel change. The test plan alternates reference tests and candidate tests 3 times per day (when performing RRR CCC RRR CCC) tests and the triplicate engine maps (versus 1) do not provide any substantial

improvement in the level of information as compared to performing a single engine map after fuel drum changes. My request is that we be allowed to perform 1 engine map and comparing it to the other engine maps for that fuel after fuel changes to verify that the system is in the proper configuration. I have discussed this matter with Clifford Tyree.

Additionally, during fuel mixing, there were two drums that, after adding reference and b100, were not exactly B20. One drum, identified as MAZ 2, had a final concentration of 19.95% B100 while the other drum, identified as MAZ 4, had a final concentration of 20.02% B100. Clifford Tyree asked that calculate and add a small amount of B100 to the drum MAZ 2 which I did (36ml B100) to take it from B19.95 to B20.

So far so good on the testing. Our NOX, which had been the problem in the first attempt, is now sufficiently low that I have good confidence going forward.

Thanks,

Dave McKain

QA/QC Comments from Dr. Ben Shade received January 2, 2007

Comments and Questions – BCS 010107

World Energy TCEQ study – Nov 2006

1. How are NMHC concentrations measured? Test Plan says FID and bags using GC. Final report seems to be bag-based.
2. Justify change in number of engine maps in final report to reflect email from Morris Brown dated 11/20/06.
3. Was Sartorius (Test Plan) or Mettler-Toledo (Final Report) microbalance used?
4. Is there a procedure to mix fuel? (justification of 1 hour mixing for ~440 gal, 0.5 hour for ~55 gal)
5. Was Eco-Physics NOx used for anything in this study?
6. Table 7 in final report – Nr and n values for TPM seem to be incorrect. Any explanation?
7. Where are calibration reports, propane injections, and analyzer checks? (are they on the zip disk?)

Response

1. The NMHC concentrations are calculated by measuring the methane concentration of the dilute exhaust, making a background correction, and subtracting that concentration from that reported using the continuous FID. The exact procedures are described in 86.1342-94(b)(8) of the CFR.
2. A copy of the email communication regarding the reduction in number of engine maps performed at fuel changeover has been attached to the report in Appendix B, Supporting Documents.
3. The Sartorius microbalance was used for PM weighing and the final report has be updated to reflect that information.
4. There is no standing procedure for mixing the fuels. The one-hour mixing (for combining all of the reference fuel drums) was established during other fuel testing while the 0.5 hour mixing of the biodiesel blend stock components was a judgment call. While we have not done extensive research into mixing times, we felt that the times chosen for mixing reflected good engineering judgment such that homogenous mixtures would be obtained.
5. The Eco-Physics NOx analyzer was utilized as a QA/QC measure. While the data from that analyzer are not used as a determination during the comparison of the reference and candidate fuels, the data from a second analyzer provides assurance that NOx is being measured properly. The choice of the Eco-Physics analyzer, versus the other analyzers in inventory, was based on availability and current maintenance status.
6. Table 7 has been corrected to reflect the correct values for Nr and n for total particulate matter.
7. The calibration reports, propane injections and analyzer checks are contained in a separate document titled "World Energy QA/QC Documentation" (World Energy QA_QC Documentation.pdf) which will be supplied as a separate document to the main report.