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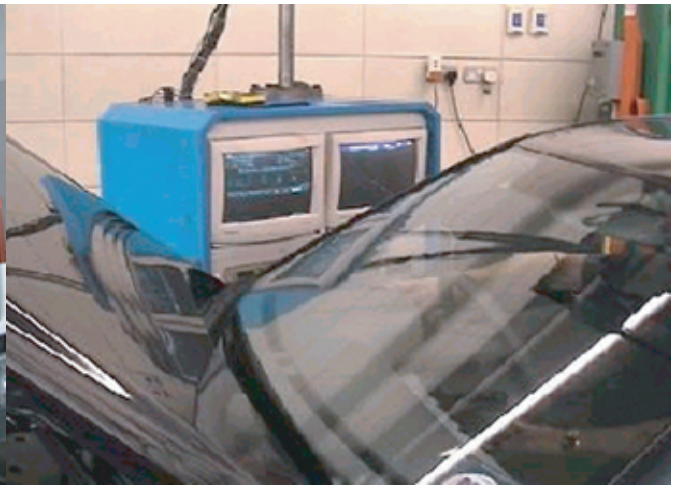
BIOFRIENDLY CORPORATION

Biofriendly Executive Summary (Abstract) and Final Toxicity Report from Southwest Research Institute



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GREEN PLUS

BIOFRIENDLY CORPORATION ABSTRACT

SwRI Project No. 03.11251

Biofriendly Corporation, operating under a grant from the Texas Commission for Environmental Quality, authorized Southwest Research Institute to conduct an independent evaluation of toxic emissions from diesel fuel with and without Biofriendly's liquid fuel combustion catalyst, Green Plus®.

A 1991 Detroit Diesel Series 60 engine was tested to provide regulated and selected toxic emission measurements from a diesel engine operating in an engine dynamometer test cell on a diesel fuel both with and without the additive. The base fuel was low sulfur No. 2 certification diesel, and the Green Plus additive was blended with the base fuel at a concentration of 0.3125 and 0.625 ml per gallon. Engine operation was performed for 25 hours with the lower concentration of the additive to condition the engine prior to testing.

Test sequences consisted of a cold- and three hot-start tests for each fuel. This report includes the regulated and selected toxic emission results for the various experiments. In general, tests conducted with the fuel containing Green Plus additive produced no differences in the selected toxic emissions. No additional interpretation of the data was performed. A detailed interpretation of the data has been left to the Biofriendly Corporation.

The protocol designed for this testing was deliberately chosen to maximize the possibility of detecting the toxic species. As stated above, the engine was operated for 25 hours in order to allow the Green Plus to complete a conditioning period during which some emissions may increase. After this period, emissions generally decline significantly below baseline. Biofriendly reasoned that if any new toxic or any increase in existing toxics were going to occur, it would be during this period.

It is important to note that in the TxLED testing at 25 hours, emissions reductions had only just begun. This is also true in this set of data. For example, if the data is inspected closely, one will see an indication that NOx is beginning to fall.

The toxicity testing reported here includes "cold starts" and "hot starts" and is considered a severe test of the engine's ability to perform without producing toxic agents. In the results it is clear that the addition of the Green Plus Fuel Catalyst at the standard concentration level did not alter the production of toxic species and did not increase the quantity of small particles. SwRI concluded that there was no significant difference between the base fuel and the base fuel treated with Green Plus. To be absolutely sure that there were no new toxic species produced or an increase in existing species, SwRI was asked to double the concentration of Green Plus and repeat the test. This data is also included in the report.

FUEL EVALUATION PROGRAM FOR BIOFRIENDLY CORPORATION

FINAL REPORT

SwRI® Project No. 03.11251

Prepared for

Biofriendly Corporation
158 Sawpit Lane
Bradbury, CA 91010

Prepared by

E. Robert Fanick
Group Leader

June 2005

FUEL EVALUATION PROGRAM FOR BIOFRIENDLY CORPORATION

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DEPARTMENT OF ENGINE AND EMISSIONS RESEARCH
ENGINE, EMISSIONS, AND VEHICLE RESEARCH DIVISION

This report shall not be reproduced, except in full, without the written approval of Southwest Research Institute®.
Results and discussion given in this report relate only to the test items described in this report.

FOREWORD

This project was performed for Biofriendly Corporation under SwRI Project 03-11251. The technical representative for Biofriendly Corporation was Dr. Colin Hill. The Principal Investigator and Project Leader for SwRI was Mr. E. Robert Fanick, Group Leader in the Department of Engine and Emissions Research. SwRI technical personnel involved in engine operation, emissions sampling, and emissions analysis included Messrs. Ricky D. Frierson, Staff Technician, and Johnny Cantu, Technician. Data reduction was performed by Ms. Sylvia G. Niño, Ms. Amanda L. Korzekwa, and Ms. Kathleen M. Jack. The SwRI Project Manager for this work was Dr. Lawrence R. Smith, Manager of the Light-Duty and Unregulated Emissions Section.

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EXECUTIVE SUMMARY

A 1991 Detroit Diesel Series 60 engine was tested to provide the Biofriendly Corporation with regulated and selected toxic emission measurements from a diesel engine operating in an engine dynamometer test cell on a diesel fuel both with and without an additive. The base fuel was a low sulfur No. 2 certification diesel, and the Green Plus additive was blended with the base fuel at a concentration of 0.3125 and 0.625 ml per gallon. Engine operation was performed for 25 hours with the lower concentration of the additive to condition the engine prior to testing.

Test sequences consisted of a cold- and three hot-start tests for each fuel. This report includes the regulated and selected toxic emission results for the various experiments. In general, tests conducted with the fuel containing Green Plus additive produced no differences in the selected toxic emissions. No additional interpretation of the data was performed. A detailed interpretation of the data has been left to the Biofriendly Corporation.

1.0 INTRODUCTION

This work was performed for Biofriendly Corporation. A 1991 Detroit Diesel Series 60 engine was used as the emissions test bed in this project. Testing was performed with a low sulfur No. 2 diesel fuel and the same fuel blended with Green Plus additive supplied by the Biofriendly Corporation. Regulated exhaust emissions (total hydrocarbons, THC; carbon monoxide, CO; oxides of nitrogen, NO_x; and particulate), and carbon dioxide (CO_2) were evaluated for all tests. Brake specific fuel consumption (BSFC) was calculated using carbon balance techniques. The selected toxic emissions included a number of toxic compounds from the Environmental Protection Agency's (EPA) list of mobile source air toxics including:

- 1,3-Butadiene
- Benzene
- Toluene
- Xylenes (ortho-, meta-, and para-)
- Ethyl benzene
- Formaldehyde
- Acetaldehyde
- n-Hexane
- Styrene
- Acrolein.

In addition, a particle size distribution was performed during the cold- and one of the hot-starts for the base fuel and the fuel base fuel blended with the lowest concentration of Green Plus.

2.0 HEAVY-DUTY ENGINE TESTING

2.1 Objective

The objective of this program was to provide Biofriendly Corporation with regulated and selected toxic emission measurements from a diesel engine operating in an engine dynamometer test cell on a diesel fuel both with and without an additive. All tests were performed according to 40 CFR 86 Subpart N.

2.2 Scope of Work

2.2.1 Test Protocol

Emission testing was conducted utilizing the EPA transient test protocol. Table 1 presents the test plan for the heavy-duty engine testing. The test plan began with 25 hours of engine operation with the base fuel followed by a cold- and three hot-start EPA transient test sequence. This test sequence established the baseline regulated and toxic emissions. The fuel was then changed to the base fuel blended with Green Plus additive. Engine operation was performed for 25 hours with this fuel blend, and an additional cold- and three hot-start EPA transient test sequence was conducted. An additional test with a higher concentration of the additive was also performed after 4 additional hours of engine operation. At the completion of testing with the fuel blends, the engine was once again operated for 25 hours with the base fuel and retested with a cold- and three hot-start test sequence (regulated emissions only) to confirm that the engine emissions have returned to their original baseline levels.

Under the transient Federal Test Procedure (FTP), the transient cycle is described by means of percent of maximum torque and percent of rated speed for each one-second interval over a test cycle of 1199 seconds duration. To generate a transient cycle, an engine's full load torque curve is obtained from an engine speed below curb idle speed to maximum no-load engine speed. Data from this "torque curve," or torque map, are used with the specified speed and load percentages to form a transient cycle. A graphic presentation of the speed and torque commands which constitute a transient cycle is given in Figure 1 for illustration purposes. The first five minutes of the cycle is designated as the New York Non-Freeway (NYNF) portion of the test and represents city operation with extensive idle time. The second five minutes is called the Los Angeles Non-Freeway (LANF) portion. This part of the test also represents city operation, but without the extensive idle time. The third five-minute section of the test is called the Los Angeles Freeway (LAF) portion. This part is more representative of higher speed conditions indicative of freeway operation. The final five minutes of the transient cycle is a repeat of the NYNF portion. These four parts are combined to give the transient cycle.

In general, a transient test consists of both cold-start and hot-start transient cycle operation. The same engine command cycle is used in both cases. For the cold-start, the diesel engine is operated over a "prep" cycle, and then allowed to stand overnight in an ambient soak at a temperature between 68 and 86°F. The cold-start transient cycle begins when the engine is cranked for cold start-up. Upon completion of the cold-start transient cycle, the engine is stopped and allowed to stand for

TABLE 1. TEST PLAN FOR HEAVY-DUTY TESTING

Step	Description
1	Obtain engine, install in a transient-capable test cell, and check engine condition with the base fuel (EM-5402-F). Perform engine operation for 25 hours at rated speed and 25%, 50%, and 75% load for one hour at each load condition continuously throughout the durability.
2	Perform emission instrument calibrations as required. Calibrate torque meter and check signal conditioning systems. Validate Constant Volume Sampler (CVS) gaseous and particulate sampling systems using propane recovery techniques.
3	Operate engine at rated speed and full load for approximately 10 minutes, then power validate engine.
4	Conduct transient "full-throttle" torque map from low- to high-idle and save resulting transient command cycle.
5	Run two 20-minute practice transient cycles without engine-off soak between cycles, and adjust dynamometer controls to meet statistical limits for transient cycle operation.
6	Soak engine overnight. Run a cold-start transient cycle, soak engine for 20 minutes, run three hot-start transient cycles with a 20 minute soak between each cycle, and conduct hydrocarbon speciation for selected toxic emissions, and conduct evaluation for the regulated emissions THC, CO, NO_x, and total particulate emissions during each test.
7	Change fuel to base fuel blended with additive at a concentration of 0.3125 ml per gallon (EM-5476-F). Perform engine operation for 25 hours (cycle to be the same as used in Step 1). Repeat Steps 2 through 6.
8	Change fuel to base fuel blended with additive at a concentration of 0.625 ml per gallon (EM-5488-F). Perform engine operation for 4 hours (cycle to be the same as used in Step 1). Repeat Steps 2 through 6.
9	At the completion of testing in Step 8, operate the engine at rated speed and load for 25 hours to purge all traces of the additive from the test engine. Repeat Steps 3 through 6 to confirm a return to the original baseline emission levels. No samples were collected for hydrocarbon speciation during this step.

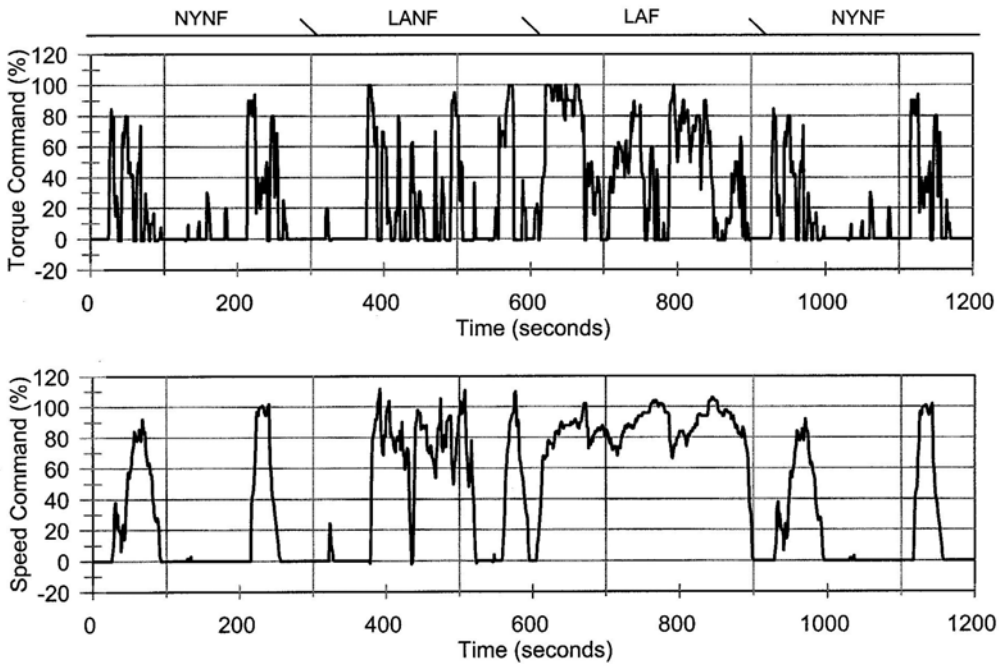

FIGURE 1. GRAPHIC REPRESENTATION OF TORQUE AND SPEED COMMANDS FOR THE TRANSIENT CYCLE FOR HEAVY-DUTY ENGINES

20 minutes. After this hot-soak period, a hot-start transient cycle begins with engine cranking. In order to determine how well the engine followed the transient command cycle, engine performance is compared to engine command, and several statistics are computed. These computed statistics must be within tolerances specified in the Code of Federal Regulations (CFR). In addition to statistical parameters, the cycle work actually produced should be between 5 percent above and 15 percent below the work requested by the command cycle.

2.2.2 Engine Selection and Description

For the purpose of testing, Biofriendly Corporation selected a 1991 heavy-duty, on-highway, Detroit Diesel Series 60 (Serial No. 06RE001123) engine. This engine was an inline, six-cylinder configuration rated for 355 hp at 1800 rpm. It was turbocharged and used a laboratory water-to-air heat exchanger for a charge air intercooler. Table 2 lists the engine specifications and features, and Figure 2 illustrates the engine speed and torque map for this engine operating on No. 2 certification diesel.

2.2.3 Test Fuel

Three test fuels were utilized in this study. Two of the fuels contained Green Plus. The test fuels included:

TABLE 2. ENGINE SPECIFICATIONS AND FEATURES

Engine Parameter	Comment
Engine Serial Number	06RE001123
Make	Detroit Diesel
Model	Series 60, 6067GU60
Engine Displacement and Configuration	12.7 L, I-6
Emission Family	MDD12.7FZAK
Rated Power	355 bhp at 1800 rpm
Peak Torque	1450 lb-ft at 1200 rpm
Idle Speed	600 rpm
Electronic Control Module	DDEC-II
Aspiration	Turbocharged

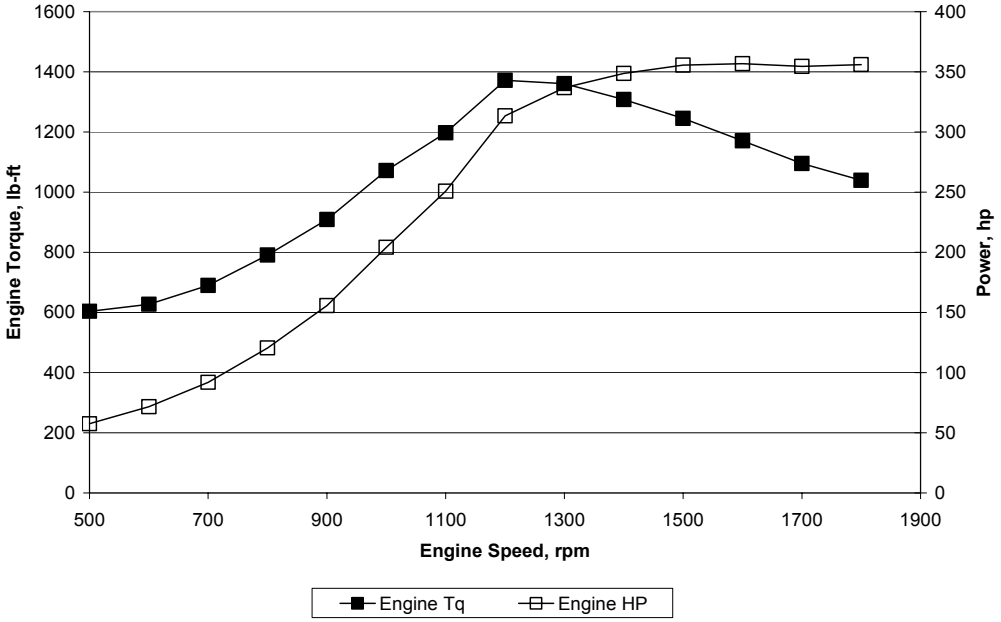

FIGURE 2. SPEED AND TORQUE MAP FOR 1991 DETROIT DIESEL SERIES 60 12.7 L HEAVY-DUTY DIESEL ENGINE

- Low sulfur No. 2 certification diesel (EM-5402-F)
- Low sulfur No. 2 certification diesel blended with 0.3125 ml per gallon of Green Plus (EM-5476-F)
- Low sulfur No. 2 certification diesel blended with 0.625 ml per gallon of Green Plus (EM-5488-F).

The base fuel was analyzed for selected fuel properties, and the results of these analyses are presented in Table 3.

TABLE 3. FUEL ANALYSIS RESULTS

Fuel Code	EM-5402-F
	No. 2
API Gravity	36.23
Sulfur, wt%	0.03469
Cetane Number	46.4
Cetane Index	47.6
Carbon, wt%	86.79
Hydrogen, wt%	13.21
Aromatics, vol %	29.4
Olefins, vol %	1.2
Saturates, vol %	69.4
Viscosity at 40C (cs)	2.53
Flash Point, °F	148.5
IBP, °F	358.0
5%, °F	389.8
10%, °F	409.8
20%, °F	437.5
30%, °F	459.3
40%, °F	479.8
50%, °F	498.7
60%, °F	517.3
70%, °F	536.5
80%, °F	559.8
90%, °F	590.0
95%, °F	620.1
EP, °F	645.8

2.2.4. Select Toxic Hydrocarbons

The selected toxic hydrocarbon compounds were determined by a technique called hydrocarbon speciation. Analytical procedures for conducting the hydrocarbon speciation (C_1 to C_{12} hydrocarbons, aldehydes, and ketones) were similar to the CRC Auto/Oil Phase II methods. With these methods, exhaust emissions samples are analyzed for the presence of more than 200 different exhaust species. A three gas chromatograph (GC) procedure and one High Performance Liquid Chromatography (HPLC) procedure were used to identify and quantify specific compounds. One GC is used for C_2-C_4 species, a second for C_5-C_{12} species, and a third is used to separate 1-methylcyclopentane, benzene, toluene, and 2,3,3-trimethylpentane, which co-elute and cannot be accurately quantified by other methods. In general, all emission "sample" bags were analyzed

before the "background" bags, so that reactive exhaust compounds could be analyzed as quickly as possible. A brief description of these procedures is given below.

2.2.4.1. C_2-C_4 Species

With the aid of a DB-WAX pre-column and a 10-port switching valve, the first GC procedure allows the separation and determination of exhaust concentrations of C_2-C_4 individual hydrocarbon species, including: ethane; ethylene; acetylene; propane; propylene; propadiene; butane; trans-2-butene; 1-butene; 2-methylpropene; 2,2-dimethylpropane; propyne; 1,3-butadiene; 2-methylpropane; 1-butyne; and cis-2-butene. Bag samples were analyzed with a GC system which utilized a Hewlett-Packard Model 5890 Series II GC with an FID, two pneumatically operated and electrically controlled valves, and two analytical columns. The carrier gas was helium. The C_2-C_4 hydrocarbons were separated from the higher molecular weight hydrocarbons and polar compounds. The higher molecular weight hydrocarbons (and water and alcohols) were retained on the pre-column while the C_2-C_4 hydrocarbons passed through to the analytical column. While the C_2-C_4 hydrocarbons were separated on the analytical column, the pre-column was back-flushed with helium to prepare for the next run. Because the sample passes directly from the sampling valve to the column (without passing through a split/split less injector), the amount of sample delivered to the column is determined by the size of the sample loop and its temperature. The column flow was set by fine-tuning the column head pressure to give butane a retention time of 5.25 ± 0.05 minutes. The GC was calibrated daily using a CRC Auto/Oil 23-component calibration mixture. Detection limits for the procedure were on the order of 5 ppbC in dilute exhaust for all compounds.

2.2.4.2. C_5-C_{12} Species

The second GC procedure provides separation and exhaust concentrations for more than 100 C_5-C_{12} individual hydrocarbon compounds. Bag samples were analyzed using a gas chromatograph equipped with an FID. The GC system utilized a Hewlett-Packard Model 5890 Series II GC with an FID, a pneumatically operated and electrically controlled valve, and a DB-1 fused silica open tubular column (FSOT). The carrier gas was helium. Gaseous sample was pumped from the bag through a sample loop on the gas sampling valve and was then introduced into the liquid nitrogen cooled column. The column oven was then programmed to a maximum temperature of 200°C. The analog signal from the FID was sent to a networked computer system via a buffered analog to digital converter. Column flow was set by fine-tuning the column head pressure to give propane a retention time of 5.40 ± 0.10 minutes using a temperature program. The GC was calibrated daily using a CRC Auto/Oil 23-component calibration mixture. Detection limits for the procedure are on the order of 10 ppbC in dilute exhaust for all compounds.

2.2.4.3. Benzene and Toluene

The third GC procedure uses a separate system configured similarly to the second GC method (but utilizing a DB-5 analytical column instead of a DB-1 FSOT column) to determine individual concentrations of benzene and toluene according to the CRC Auto/Oil Phase II Protocols. Separation of benzene and toluene from co-eluting peaks was carried out by fine-tuning the column head pressure to give benzene a retention time of 22-23 minutes. The GC was calibrated daily using a CRC 7-component calibration mixture.

2.2.4.4. Aldehydes and Ketones

An HPLC procedure was utilized for the analysis of aldehydes and ketones. Samples were collected by bubbling dilute exhaust at a nominal flowrate of 4 L/min through chilled glass impingers containing an acetonitrile solution of 2,4-DNPH and perchloric acid. For analysis, a portion of the acetonitrile solution was injected into a liquid chromatograph equipped with a UV detector. External standards of the aldehyde and ketone DNPH derivatives were used to quantify the results. The aldehydes and ketones measured were: formaldehyde, acetaldehyde, acrolein, acetone, propionaldehyde, crotonaldehyde, isobutyraldehyde/methylethylketone (not resolved from each other during normal operating conditions, and so split equally between the two compounds), benzaldehyde, valeraldehyde, o-tolualdehyde, m-tolualdehyde/p-tolualdehyde (not resolved from each other during normal operating conditions, and so reported together), and hexanaldehyde. Detection limits for this procedure are on the order of 0.005 ppm aldehyde or ketone in dilute exhaust.

2.2.5. Particle Size Distribution

Particle size distribution was determined using a Model 110 Micro-Orifice Uniform Deposit Impactor (MOUDI) and an isokinetic sampling probe. The flow rate through the MOUDI was 30 L/min. Stages 3 through 10 were used to collect particulate mass at equivalent aerodynamic diameter cut-offs of greater than 6.2 µm, 3.1 µm, 1.8 µm, 1.0 µm, 0.54 µm, 0.31 µm, 0.17 µm, 0.09 µm, and 0.056 µm. The last stage was followed by a backup filter to collect particles below 0.056 µm. The particles were collected on uncoated 47-mm aluminum foil substrates.

The MOUDI operates the same as any inertial cascade impactor with multiple nozzles. At each stage, jets of particle-laden air impinge upon an impaction plate. Particles larger than the equivalent aerodynamic diameter cut-size of that stage have more inertia and cross the air streamlines. Upon contact with the stage, the particles remain on the impaction plate. Smaller particles have less inertia. Because the smaller particles cannot cross the streamlines, these small particles proceed to the next stage. Smaller nozzles with higher air velocity collect finer particles. The process continues through the cascade impactor until the smallest particles are collected on the final glass fiber backup filter. By rotating every other stage of the impactor and holding the others stationary, every nozzle plate/impaction plate combination has relative rotation. This rotation allows the MOUDI to achieve near uniform particle deposition.

3.0 TEST RESULTS

3.1 Regulated Transient Emission Test Results

Regulated emission tests were performed on exhaust from a 1991 Detroit Diesel Series 60 diesel engine. Three fuels were tested during this project. Table 4 summarizes the regulated emission results for the EPA transient tests. Appendix A contains the individual and composite emission test results.

3.2 Toxic Emissions

Speciation of the volatile hydrocarbon compounds with carbon numbers from C_2-C_{12} was performed for each segment of the EPA transient tests. More than 200 compounds were checked for their presence in the dilute exhaust. Data for the individual compounds are included in Appendix B. Some compounds were found only in one test and not in the others. When compounds were found at concentrations less than 0.1 mg/bhp-hr, they were labeled at "trace" in the Appendix tables. A number of selected toxic emissions were detected in the exhaust with the base fuel and with the Green Plus additive. Table 5 compares the composite results for the list of selected toxic emissions.

3.3 Particle Size Distribution

Particle size distribution was determined using a MOUDI, an isokinetic sampling probe, and a sampling rate of about 30 L/min. Stages 3 through 10 of the MOUDI were used to collect particulate mass at equivalent aerodynamic diameter cut-offs of greater than 6.2 µm, 3.1 µm, 1.8 µm, 1.0 µm, 0.54 µm, 0.31 µm, 0.17 µm, 0.09 µm, and 0.056 µm. The last stage was followed by a backup filter to collect particles below 0.056 µm. Table 6 shows equivalent aerodynamic particle size distribution data, and Figures 3 through 5 present a visual representation of the cut-off diameters by size range for the base fuel and the base fuel blended with Green Plus.

In general, no significant difference was noted between the two fuels, the particle size distribution was bi-modal, and the majority of the particle mass was less than 0.54 µm in diameter. The largest particulate mass for both fuels was found in the size range less than 0.056 µm. In terms of $PM_{2.5}$, more than 91 percent of the particles were less than 2.5 µm in equivalent aerodynamic cutoff diameter for both fuels, and all of the particles were less than 10µm. Table 7 compares the equivalent aerodynamic cutoff diameters for both fuels.

TABLE 4. SUMMARY OF REGULATED EMISSIONS FOR DETROIT DIESEL SERIES 60

Test Number	Fuel	Additive	Emissions Results, g/bhp-hr				Brake Specific Fuel Consumption lb/bhp-hr
			HC	CO	NO_x	Part.	
1991 Standard			1.3	15.5	5.0	0.60	NS[a]
BASE C1	No. 2[b]	--[c]	0.045	2.919	5.554	0.192	0.333
BASE H1	No. 2	--	0.037	2.553	4.826	0.200	0.381
Composite C1-H1	No. 2	--	0.038	2.605	4.931	0.199	0.374
BASE H2	No. 2	--	0.047	2.463	4.833	0.191	0.377
Composite C1-H2	No. 2	--	0.047	2.528	4.936	0.191	0.371
BASE H3	No. 2	--	0.027	2.336	5.029	0.209	0.364
Composite C1-H3	No. 2	--	0.030	2.422	5.107	0.206	0.359
Average of Composites	No. 2	--	0.038	2.518	4.991	0.199	0.368
ADD C1	No. 2	GP[d]	0.093	3.196	5.490	0.200	0.392
ADD H1	No. 2	GP	0.077	2.561	4.800	0.197	0.376
Composite C1-H1	No. 2	GP	0.079	2.652	4.899	0.197	0.379
ADD H2	No. 2	GP	0.064	2.388	4.817	0.197	0.363
Composite C1-H2	No. 2	GP	0.068	2.461	4.914	0.197	0.367
ADD H3	No. 2	GP	0.075	2.520	4.799	0.201	0.374
Composite C1-H3	No. 2	GP	0.078	2.617	4.898	0.200	0.376
Average of Composites	No. 2	GP	0.075	2.577	4.904	0.198	0.374
ADD2 C1	No. 2	GP2[e]	0.071	3.128	5.649	0.213	0.407
ADD2 H1	No. 2	GP2	0.068	2.620	4.818	0.211	0.383
Composite C1-H1	No. 2	GP2	0.068	2.693	4.937	0.211	0.387
ADD2 H2	No. 2	GP2	0.054	2.584	4.877	0.216	0.379
Composite C1-H2	No. 2	GP2	0.056	2.662	4.988	0.216	0.383
ADD2 H3	No. 2	GP2	0.086	2.560	4.815	0.208	0.389
Composite C1-H3	No. 2	GP2	0.084	2.642	4.935	0.209	0.391
Average of Composites	No. 2	GP2	0.069	2.666	4.953	0.212	0.387
BASE C2	No. 2	--	0.065	3.284	5.710	0.218	0.397
BASE H4	No. 2	--	0.061	2.714	4.938	0.225	0.383
Composite C2-H4	No. 2	--	0.062	2.795	5.048	0.224	0.385
BASE H5	No. 2	--	0.067	2.680	4.948	0.202	0.380
Composite C2-H5	No. 2	--	0.066	2.766	5.057	0.205	0.383
BASE H6	No. 2	--	0.058	2.666	4.912	0.222	0.386
Composite C2-H6	No. 2	--	0.059	2.753	5.025	0.221	0.388
Average of Composites	No. 2	--	0.062	2.771	5.043	0.217	0.385

[a] NS – No standard
[b] No. 2 – No. 2 diesel
[c] No additive for this test.
[d] GP – Green Plus additive at a concentration of 0.3125 ml per gallon
[e] GP2 - Green Plus additive at a concentration of 0.625 ml per gallon

TABLE 5. SELECTED TOXIC EMISSIONS

Compounds	Test Number, mg/hp-hr							
	BASE C1	BASE H1	BASE H2	BASE H3	ADD C1	ADD H1	ADD H2	ADD H3
1,3-Butadiene	1.2	1.4	1.3	1.1	1.7	1.5	1.4	1.5
Hexane	0.2	ND	ND	ND	0.2	0.2	0.3	0.3
Benzene	1.2	1.1	0.9	0.8	1.4	1.1	0.8	0.8
Toluene	0.8	0.6	0.4	0.2	1.5	0.6	0.4	0.7
Ethyl benzene	0.2	0.3	0.2	ND	0.3	0.3	ND	0.2
m- & p-Xylene	ND	0.2	ND	ND	0.4	0.4	ND	0.2
o-Xylene	ND	ND	ND	ND	ND	ND	ND	ND
Styrene	ND	ND	ND	ND	ND	ND	ND	ND
Formaldehyde	11.7	10.3	9.3	10.4	18.0	12.7	12.4	12.2
Acetaldehyde	4.5	4.1	3.8	4.2	6.2	4.3	4.3	4.2
Acrolein	0.4	0.3	0.4	0.4	1.2	0.9	0.9	0.9

TABLE 6. HEAVY-DUTY ENGINE EXHAUST PARTICLE SIZE DISTRIBUTION

Equivalent Aerodynamic Cutoff Diameter	Cold-Start Tests				Hot-Start Tests			
	Base		Additive		Base		Additive	
	Percent	mg/bhp-hr	Percent	mg/bhp-hr	Percent	mg/bhp-hr	Percent	mg/bhp-hr
>6.2 µm	2.4	5.1	1.1	2.3	3.0	5.9	3.9	8.4
6.2-3.1 µm	2.9	6.0	1.4	2.8	2.7	5.4	3.9	8.4
3.1-1.8 µm	3.8	8.0	4.9	10.2	2.8	5.6	3.5	7.6
1.8-1.0 µm	3.0	6.3	2.9	5.9	4.2	8.4	4.8	10.4
1.0-0.54 µm	7.6	15.9	4.5	9.3	6.0	12.1	4.3	9.3
0.54-0.31 µm	12.8	26.8	13.9	28.6	13.4	26.8	14.2	30.7
0.31-0.17 µm	17.3	36.2	14.6	30.0	15.3	30.7	15.9	34.4
0.17-0.09 µm	17.2	36.0	18.0	37.1	18.2	36.4	18.4	39.7
0.09-0.06 µm	7.0	14.7	10.0	20.7	9.5	19.0	8.9	19.2
<0.06 µm	25.9	54.1	28.7	59.1	24.8	49.7	22.2	47.9

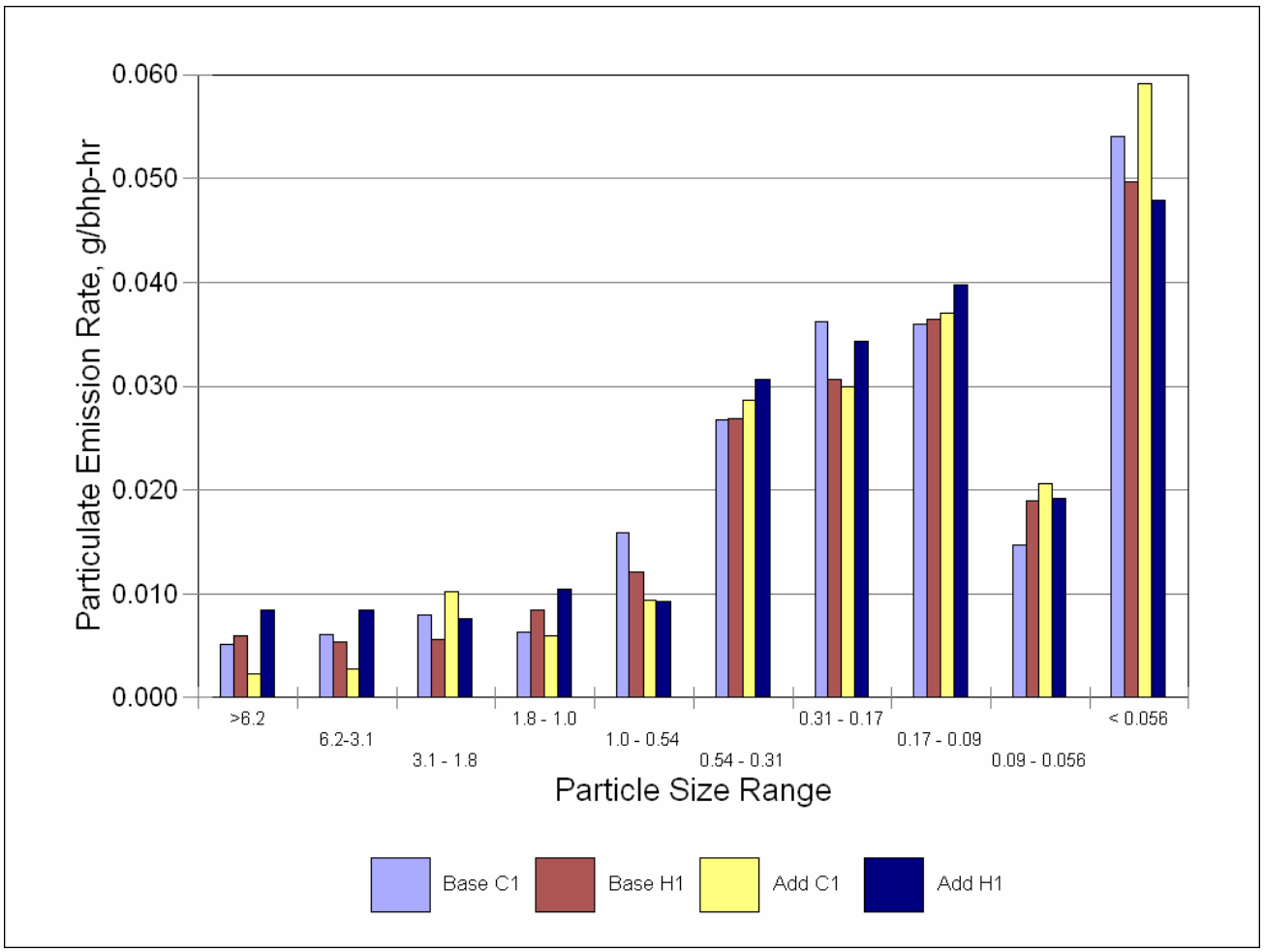

FIGURE 3. EQUIVALENT AERODYNAMIC DIAMETER PARTICLE SIZE DISTRIBUTION

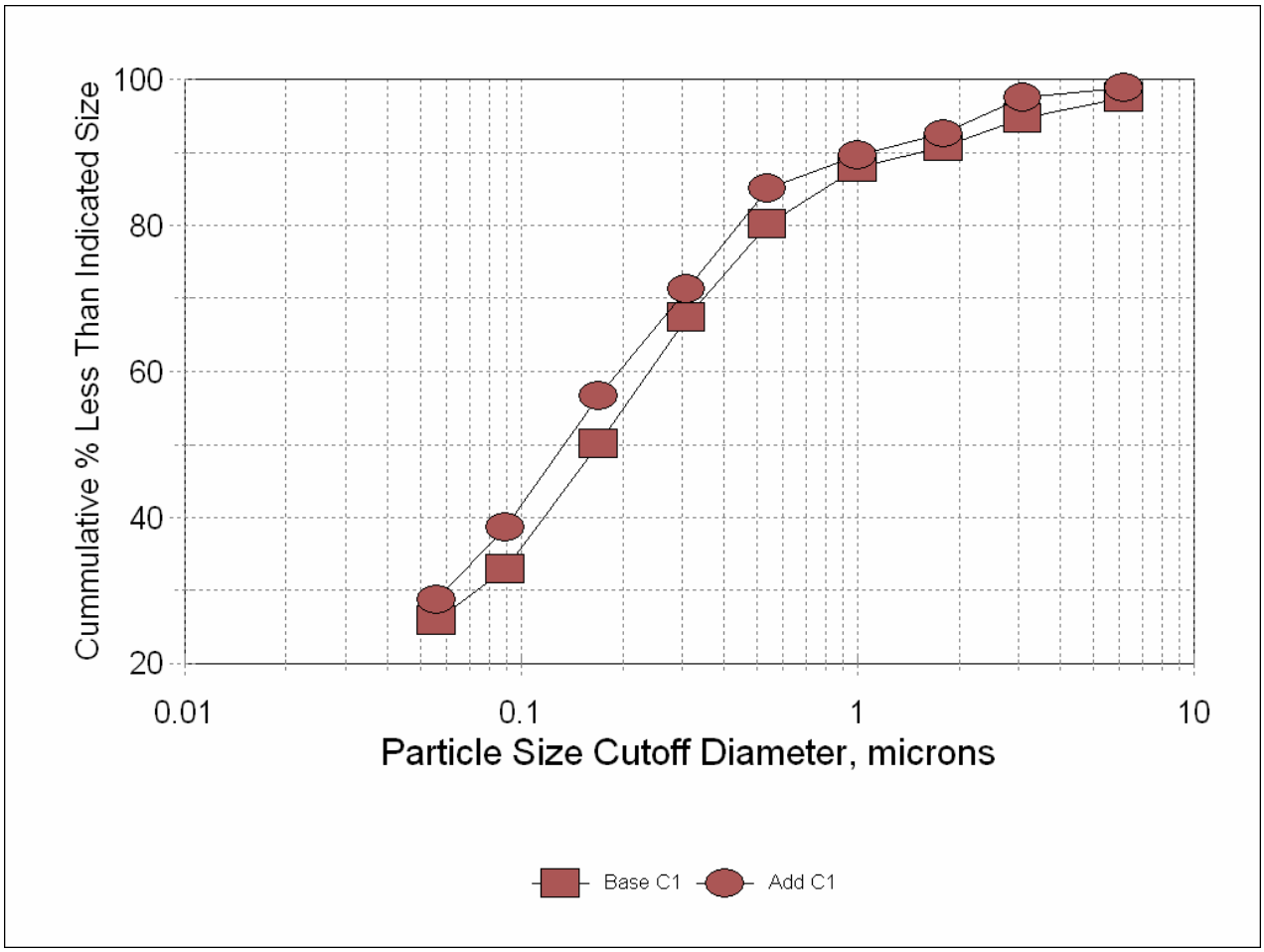

FIGURE 4. CUMULATIVE PERCENT LESS THAN INDICATED PARTICLE SIZE FOR THE COLD-START TESTS

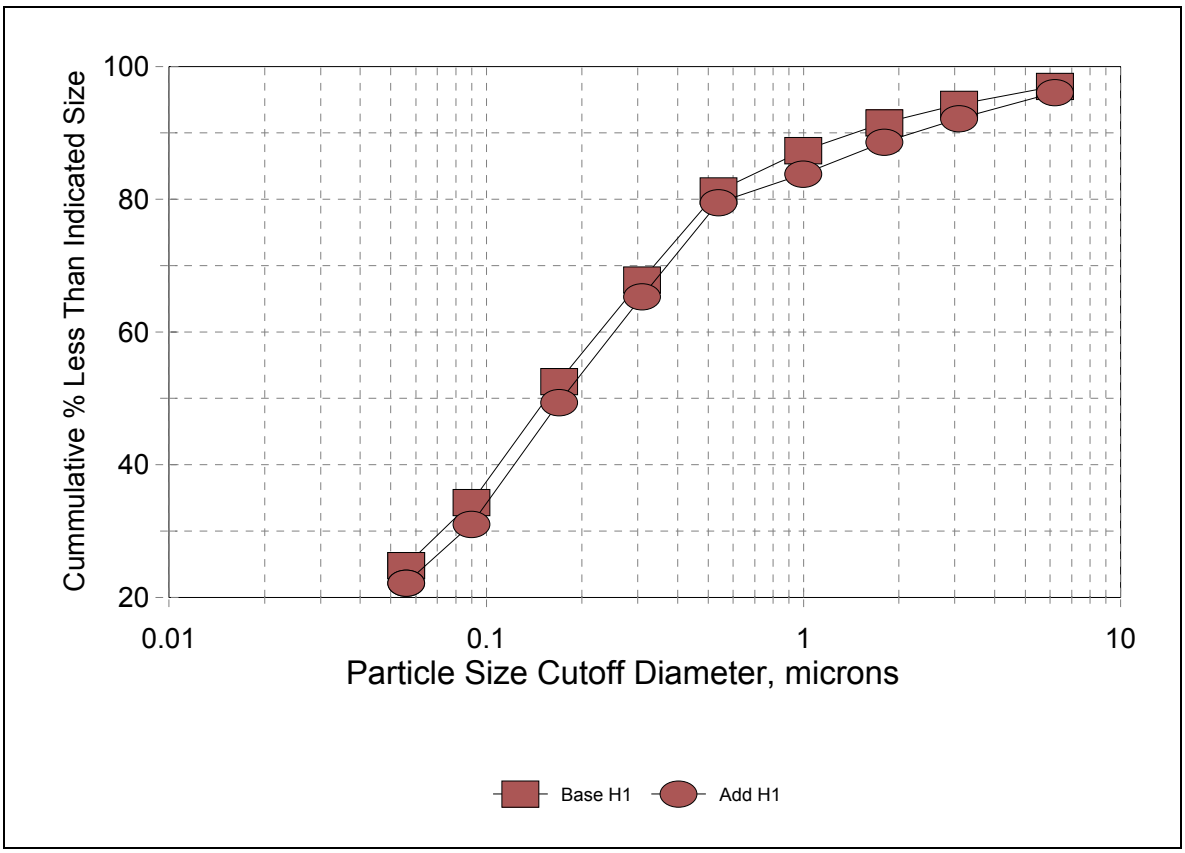

FIGURE 5. CUMULATIVE PERCENT LESS THAN INDICATED PARTICLE SIZE FOR THE HOT-START TESTS

TABLE 7. SELECTED EQUIVALENT AERODYNAMIC CUTOFF DIAMETERS

Cutoff Diameter	Base C1	Additive C1	Base H1	Additive H1
10	100	100	100	100
7.5	98.8	98.4	98.1	97.7
5	96.5	98.4	96.0	97.7
2.5	92.9	95.2	93.1	90.6

4.0 SUMMARY

Testing was performed to provide Biofriendly Corporation with data on regulated and selected toxic emissions from a diesel engine operating both with and without an additive. A 1991 Detroit Diesel Series 60 engine was tested according to procedures established in 40 CFR 86 Subpart N. Evaluations were conducted to document any differences between the baseline emissions and the base fuel blended with Green Plus. A cold- and three hot-start tests were used to evaluate each fuel. In general, the fuels containing Biofriendly Corporation additive produced little or no differences in the emissions when compared to fuel without the additive. Due to the nature of the testing and to the limited number of repeat tests performed at each condition; further interpretation is left to Biofriendly Corporation.

APPENDIX A

HEAVY-DUTY TRANSIENT EMISISON TEST RESULTS

Pages	Test No.
A-1	BASE C1
A-2	BASE H1
A-3	Composite of BASE C1 and BASE H1
A-4	BASE H2
A-5	Composite of BASE C1 and BASE H2
A-6	BASE H3
A-7	Composite of BASE C1 and BASE H3
A-8	ADD C1
A-9	ADD H1
A-10	Composite of ADD C1 and ADD H1
A-11	ADD H2
A-12	Composite of ADD C1 and ADD H2
A-13	ADD H3
A-14	Composite of ADD C1 and ADD H3
A-15	ADD2 C1
A-16	ADD2 H1
A-17	Composite of ADD2 C1 and ADD2 H1
A-18	ADD2 H2
A-19	Composite of ADD2 C1 and ADD2 H2
A-20	ADD2 H3
A-21	Composite of ADD2 C1 and ADD2 H3
A-22	BASE C2
A-23	BASE H4
A-24	Composite of BASE C2and BASE H4
A-25	BASE H5
A-26	Composite of BASE C2and BASE H5
A-27	BASE H6
A-28	Composite of BASE C2and BASE H6

Southwest Research Institute - Department of Emissions Research
EPA Cold Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	BASE C1	, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/09/2005	Time: 09:44	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	29.22	in Hg	98.9 kPa
Engine Inlet Air			
Temperature:	75.0	°F	23.9 °C
Dew Point:	56.3	°F	13.5 °C
Abs. Humidity:	69.4	gr/lb	9.9 g/kg
Rel. Humidity:	52	%	
Dilution Air:			
Temperature:	71.0	°F	21.7 °C
Abs. Humidity	47.9	gr/lb	6.8 g/kg
Rel. Humidity:	41	%	

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,137.0	60.52
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.59	0.04
Gas Meter 2:	3.21	0.09
Sample Rate:	1.62	0.05
Total Flow Rate:	2,138.58	60.57

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.67	ppm	
HC Bckgrd	n/a		4.30	ppm	
CO Sample	51.7	2	50.51	ppm	(Dry)
CO Bckgrd	n/a	2	0.00	ppm	
NOx Sample	n/a		58.96	ppm	(Dry)
NOx Bckgrd	0.3	1	0.08	ppm	
CO2 Sample	68.0	1	0.5524	%	(Wet)
CO2 Bckgrd	7.9	1	0.0431	%	
CH4 Sample	n/a	n/a	1.88	ppm	(1.00)
CH4 Bckgrd	n/a	n/a	1.90	ppm	

Particulate Data

Filter Number:		
Weight Gain:	3.521	mg
Sample Multiplier:	1.317	

Correction Factors

NOx Humidity CF:	0.986
Dry-to-Wet CF, Sample:	0.984
Dry-to-Wet CF, Bckgrd:	0.989
Dilution Factor:	24.32

Test Cycle Data

Sample Time:	1,214.50	sec		
Work:	24.11	hp-hr	17.98	kW-hr
Reference Work:	24.14	hp-hr	18.00	kW-hr
Total Volume (Vmix):	43,288.5	scf	1,225.96	scm

Corrected Concentrations

HC	1.55	ppm	
CO	49.30	ppm	
NOx	57.95	ppm	
CO2	0.5111	%	
CH4	0.06	ppm	(1.00)

Brake-Specific Emission Results

FIDHC (Cell)	0.045	g/hp-hr	0.061	g/kW-hr
CO	2.919	g/hp-hr	3.914	g/kW-hr
NOx (Cell)	5.554	g/hp-hr	7.448	g/kW-hr
Particulate	0.192	g/hp-hr	0.258	g/kW-hr
CO2	475.4	g/hp-hr	637.54	g/kW-hr
BSFC	0.333	lb/hp-hr	0.202	kg/kW-hr
NMHC	0.039	g/hp-hr	0.053	g/kW-hr
CH4	0.002	g/hp-hr	0.003	g/kW-hr

Mass Emissions

HC		1.091	grams	
CO		70.366	grams	
NOx		133.909	grams	
Particulate		4.637	grams	
CO2		11.462	kg	
CH4		0.048	grams	
Fuel	8.03 lb		3.64 kg	

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	BASE H1	, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/09/2005	Time: 10:25	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	29.22	in Hg	98.9 kPa
Engine Inlet Air			
Temperature:	77.0	°F	25.0 °C
Dew Point:	56.8	°F	13.8 °C
Abs. Humidity:	70.7	gr/lb	10.1 g/kg
Rel. Humidity:	50	%	
Dilution Air:			
Temperature:	74.0	°F	23.3 °C
Abs. Humidity	51.6	gr/lb	7.4 g/kg
Rel. Humidity:	40	%	

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,180.6	61.76
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.58	0.04
Gas Meter 2:	3.26	0.09
Sample Rate:	1.67	0.05
Total Flow Rate:	2,182.28	61.80

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.72	ppm	
HC Bckgrd	n/a		4.70	ppm	
CO Sample	44.3	2	43.15	ppm	(Dry)
CO Bckgrd	n/a	2	0.00	ppm	
NOx Sample	n/a		49.92	ppm	(Dry)
NOx Bckgrd	0.3	1	0.08	ppm	
CO2 Sample	72.8	1	0.6135	%	(Wet)
CO2 Bckgrd	7.9	1	0.0431	%	
CH4 Sample	n/a	n/a	1.75	ppm	(1.00)
CH4 Bckgrd	n/a	n/a	1.89	ppm	

Particulate Data

Filter Number:	8974.0 (pair)	
Weight Gain:	3.676	mg
Sample Multiplier:	1.305	

Correction Factors

NOx Humidity CF:	0.989
Dry-to-Wet CF, Sample:	0.983
Dry-to-Wet CF, Bckgrd:	0.988
Dilution Factor:	21.95

Test Cycle Data

Sample Time:	1,214.40	sec		
Work:	24.01	hp-hr	17.90	kW-hr
Reference Work:	24.14	hp-hr	18.00	kW-hr
Total Volume (Vmix):	44,169.3	scf	1,250.90	scm

Corrected Concentrations

HC	1.23	ppm	
CO	42.08	ppm	
NOx	48.98	ppm	
CO2	0.5724	%	
CH4	0.05	ppm	(1.00)

Brake-Specific Emission Results

FIDHC (Cell)	0.037	g/hp-hr	0.050	g/kW-hr
CO	2.553	g/hp-hr	3.423	g/kW-hr
NOx (Cell)	4.826	g/hp-hr	6.472	g/kW-hr
Particulate	0.200	g/hp-hr	0.268	g/kW-hr
CO2	545.5	g/hp-hr	731.56	g/kW-hr
BSFC	0.381	lb/hp-hr	0.232	kg/kW-hr
NMHC	0.032	g/hp-hr	0.043	g/kW-hr
CH4	0.000	g/hp-hr	0.000	g/kW-hr

Mass Emissions

HC		0.888		grams
CO		61.286		grams
NOx		115.883		grams
Particulate		4.797		grams
CO2		13.098		kg
CH4		0.000		grams
Fuel	9.15	lb	4.15	kg

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 03/09/2005 Time: 09:44	, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4 Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123			

Test Numbers
Cold: BASE C1 Hot: BASE H1

Brake-Specific Emission Results

FIDHC (Cell)	0.038	g/hp-hr	0.051	g/kW-hr
CO	2.605	g/hp-hr	3.493	g/kW-hr
NOx (Cell)	4.931	g/hp-hr	6.612	g/kW-hr
Particulate	0.199	g/hp-hr	0.266	g/kW-hr
CO2	535.5	g/hp-hr	718.08	g/kW-hr
BSFC	0.374	lb/hp-hr	0.228	kg/kW-hr
NMHC	0.033	g/hp-hr	0.044	g/kW-hr
CH4	0.000	g/hp-hr	0.000	g/kW-hr
Work:	24.02	hp-hr	17.91	kW-hr
Reference Work:	24.14	hp-hr	18.00	kW-hr

Analyzed: 03/15/2005 14:11

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	BASE H2	, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/09/2005	Time: 11:05	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	29.21	in Hg	98.9 kPa
Engine Inlet Air			
Temperature:	78.0	°F	25.6 °C
Dew Point:	56.0	°F	13.3 °C
Abs. Humidity:	68.7	gr/lb	9.8 g/kg
Rel. Humidity:	47	%	
Dilution Air:			
Temperature:	70.0	°F	21.1 °C
Abs. Humidity	58.2	gr/lb	8.3 g/kg
Rel. Humidity:	52	%	

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,144.1	60.72
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.65	0.05
Gas Meter 2:	3.36	0.10
Sample Rate:	1.71	0.05
Total Flow Rate:	2,145.83	60.77

Particulate Data

Filter Number:	8976.0 (pair)	
Weight Gain:	3.666	mg
Sample Multiplier:	1.256	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.70	ppm	
HC Bckgrd	n/a		4.30	ppm	
CO Sample	43.8	2	42.66	ppm	(Dry)
CO Bckgrd	n/a	2	0.00	ppm	
NOx Sample	n/a		51.38	ppm	(Dry)
NOx Bckgrd	0.4	1	0.10	ppm	
CO2 Sample	73.2	1	0.6188	%	(Wet)
CO2 Bckgrd	7.8	1	0.0425	%	
CH4 Sample	n/a	n/a	1.87	ppm	(1.00)
CH4 Bckgrd	n/a	n/a	1.85	ppm	

Correction Factors

NOx Humidity CF:	0.984
Dry-to-Wet CF, Sample:	0.981
Dry-to-Wet CF, Bckgrd:	0.987
Dilution Factor:	21.76

Test Cycle Data

Sample Time:	1,214.20	sec		
Work:	24.09	hp-hr	17.96	kW-hr
Reference Work:	24.14	hp-hr	18.00	kW-hr
Total Volume (Vmix):	43,424.5	scf	1,229.81	scm

Corrected Concentrations

HC	1.60	ppm	
CO	41.44	ppm	
NOx	50.32	ppm	
CO2	0.5783	%	
CH4	0.10	ppm	(1.00)

Brake-Specific Emission Results

FIDHC (Cell)	0.047	g/hp-hr	0.063	g/kW-hr
CO	2.463	g/hp-hr	3.303	g/kW-hr
NOx (Cell)	4.833	g/hp-hr	6.481	g/kW-hr
Particulate	0.191	g/hp-hr	0.256	g/kW-hr
CO2	540.0	g/hp-hr	724.21	g/kW-hr
BSFC	0.377	lb/hp-hr	0.229	kg/kW-hr
NMHC	0.041	g/hp-hr	0.055	g/kW-hr
CH4	0.003	g/hp-hr	0.005	g/kW-hr

Mass Emissions

HC		1.130		grams
CO		59.331		grams
NOx		116.429		grams
Particulate		4.605		grams
CO2		13.010		kg
CH4		0.084		grams
Fuel	9.09	lb	4.12	kg

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 03/09/2005 Time: 09:44	, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4 Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123			

Test Numbers
Cold: BASE C1 Hot: BASE H2

Brake-Specific Emission Results

FIDHC (Cell)	0.047	g/hp-hr	0.063	g/kW-hr
CO	2.528	g/hp-hr	3.390	g/kW-hr
NOx (Cell)	4.936	g/hp-hr	6.619	g/kW-hr
Particulate	0.191	g/hp-hr	0.257	g/kW-hr
CO2	530.8	g/hp-hr	711.82	g/kW-hr
BSFC	0.371	lb/hp-hr	0.226	kg/kW-hr
NMHC	0.041	g/hp-hr	0.054	g/kW-hr
CH4	0.003	g/hp-hr	0.004	g/kW-hr
Work:	24.09	hp-hr	17.97	kW-hr
Reference Work:	24.14	hp-hr	18.00	kW-hr

Analyzed: 03/15/2005 14:11

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	BASE H3	, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/09/2005	Time: 11:45	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	29.19	in Hg	98.8 kPa
Engine Inlet Air			
Temperature:	78.0	°F	25.6 °C
Dew Point:	55.7	°F	13.2 °C
Abs. Humidity:	68.0	gr/lb	9.7 g/kg
Rel. Humidity:	46	%	
Dilution Air:			
Temperature:	76.0	°F	24.4 °C
Abs. Humidity	57.3	gr/lb	8.2 g/kg
Rel. Humidity:	42	%	

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,139.5	60.59
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.64	0.05
Gas Meter 2:	3.23	0.09
Sample Rate:	1.59	0.05
Total Flow Rate:	2,141.08	60.64

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		6.35	ppm	
HC Bckgrd	n/a		5.70	ppm	
CO Sample	40.0	2	38.89	ppm	(Dry)
CO Bckgrd	n/a	2	0.00	ppm	
NOx Sample	n/a		51.66	ppm	(Dry)
NOx Bckgrd	0.3	1	0.08	ppm	
CO2 Sample	70.1	1	0.5786	%	(Wet)
CO2 Bckgrd	7.7	1	0.0420	%	
CH4 Sample	n/a	n/a	1.77	ppm	(1.00)
CH4 Bckgrd	n/a	n/a	1.95	ppm	

Particulate Data

Filter Number:	9011.0 (pair)	
Weight Gain:	3.595	mg
Sample Multiplier:	1.346	

Correction Factors

NOx Humidity CF:	0.982
Dry-to-Wet CF, Sample:	0.982
Dry-to-Wet CF, Bckgrd:	0.987
Dilution Factor:	23.27

Test Cycle Data

Sample Time:	1,214.50	sec		
Work:	23.21	hp-hr	17.31	kW-hr
Reference Work:	24.14	hp-hr	18.00	kW-hr
Total Volume (Vmix):	43,339.0	scf	1,227.39	scm

Corrected Concentrations

HC	0.89	ppm	
CO	37.94	ppm	
NOx	50.64	ppm	
CO2	0.5384	%	
CH4	-0.09	ppm	(1.00)

Brake-Specific Emission Results

FIDHC (Cell)	0.027	g/hp-hr	0.036	g/kW-hr
CO	2.336	g/hp-hr	3.132	g/kW-hr
NOx (Cell)	5.029	g/hp-hr	6.745	g/kW-hr
Particulate	0.209	g/hp-hr	0.280	g/kW-hr
CO2	520.9	g/hp-hr	698.49	g/kW-hr
BSFC	0.364	lb/hp-hr	0.221	kg/kW-hr
NMHC	0.024	g/hp-hr	0.032	g/kW-hr
CH4	0.000	g/hp-hr	0.000	g/kW-hr

Mass Emissions

HC		0.632	grams	
CO		54.207	grams	
NOx		116.734	grams	
Particulate		4.840	grams	
CO2		12.089	kg	
CH4		0.000	grams	
Fuel	8.44 lb		3.83 kg	

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 03/09/2005 Time: 09:44	, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4 Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123			

Test Numbers
Cold: BASE C1 Hot: BASE H3

Brake-Specific Emission Results

FIDHC (Cell)	0.030	g/hp-hr	0.040	g/kW-hr
CO	2.422	g/hp-hr	3.247	g/kW-hr
NOx (Cell)	5.107	g/hp-hr	6.848	g/kW-hr
Particulate	0.206	g/hp-hr	0.276	g/kW-hr
CO2	514.2	g/hp-hr	689.50	g/kW-hr
BSFC	0.359	lb/hp-hr	0.218	kg/kW-hr
NMHC	0.026	g/hp-hr	0.035	g/kW-hr
CH4	0.000	g/hp-hr	0.000	g/kW-hr
Work:	23.34	hp-hr	17.40	kW-hr
Reference Work:	24.14	hp-hr	18.00	kW-hr

Analyzed: 03/15/2005 14:11

Southwest Research Institute - Department of Emissions Research
EPA Cold Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	ADD C1	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/18/2005	Time: 08:56	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	29.06	in Hg	98.4 kPa
Engine Inlet Air			
Temperature:	76.0	°F	24.4 °C
Dew Point:	55.2	°F	12.9 °C
Abs. Humidity:	67.0	gr/lb	9.6 g/kg
Rel. Humidity:	48	%	
Dilution Air:			
Temperature:	72.0	°F	22.2 °C
Abs. Humidity	59.8	gr/lb	8.5 g/kg
Rel. Humidity:	50	%	

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,167.3	61.38
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.64	0.05
Gas Meter 2:	3.50	0.10
Sample Rate:	1.86	0.05
Total Flow Rate:	2,169.17	61.43

Particulate Data

Filter Number:	9467.0 (pair)	
Weight Gain:	4.111	mg
Sample Multiplier:	1.165	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		7.12	ppm	
HC Bckgrd	n/a		4.20	ppm	
CO Sample	55.8	2	54.60	ppm	(Dry)
CO Bckgrd	0.1	2	0.09	ppm	
NOx Sample	n/a		57.80	ppm	(Dry)
NOx Bckgrd	0.6	1	0.15	ppm	
CO2 Sample	74.4	1	0.6348	%	(Wet)
CO2 Bckgrd	8.4	1	0.0460	%	
CH4 Sample	n/a	n/a	2.32	ppm	(1.00)
CH4 Bckgrd	n/a	n/a	2.42	ppm	

Correction Factors

NOx Humidity CF:	0.980
Dry-to-Wet CF, Sample:	0.981
Dry-to-Wet CF, Bckgrd:	0.986
Dilution Factor:	21.18

Test Cycle Data

Sample Time:	1,214.70	sec		
Work:	24.00	hp-hr	17.90	kW-hr
Reference Work:	24.21	hp-hr	18.05	kW-hr
Total Volume (Vmix):	43,914.8	scf	1,243.69	scm

Corrected Concentrations

HC	3.12	ppm	
CO	52.98	ppm	
NOx	56.54	ppm	
CO2	0.5910	%	
CH4	0.01	ppm	(1.00)

Brake-Specific Emission Results

FIDHC (Cell)	0.093	g/hp-hr	0.125	g/kW-hr
CO	3.196	g/hp-hr	4.286	g/kW-hr
NOx (Cell)	5.490	g/hp-hr	7.362	g/kW-hr
Particulate	0.200	g/hp-hr	0.268	g/kW-hr
CO2	560.2	g/hp-hr	751.30	g/kW-hr
BSFC	0.392	lb/hp-hr	0.238	kg/kW-hr
NMHC	0.081	g/hp-hr	0.108	g/kW-hr
CH4	0.000	g/hp-hr	0.001	g/kW-hr

Mass Emissions

HC		2.230	grams	
CO		76.710	grams	
NOx		131.752	grams	
Particulate		4.789	grams	
CO2		13.446	kg	
CH4		0.011	grams	
Fuel	9.41 lb		4.27 kg	

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	ADD H1	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/18/2005	Time: 09:36	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	29.05	in Hg	98.3 kPa
Engine Inlet Air			
Temperature:	76.0	°F	24.4 °C
Dew Point:	56.6	°F	13.7 °C
Abs. Humidity:	70.6	gr/lb	10.1 g/kg
Rel. Humidity:	51	%	
Dilution Air:			
Temperature:	72.5	°F	22.5 °C
Abs. Humidity	63.6	gr/lb	9.1 g/kg
Rel. Humidity:	52	%	

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,165.9	61.34
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.63	0.05
Gas Meter 2:	3.57	0.10
Sample Rate:	1.95	0.06
Total Flow Rate:	2,167.85	61.39

Particulate Data

Filter Number:	9468.10 (pair)	
Weight Gain:	4.228	mg
Sample Multiplier:	1.113	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		6.88	ppm	
HC Bckgrd	n/a		4.50	ppm	
CO Sample	44.8	2	43.65	ppm	(Dry)
CO Bckgrd	n/a	2	0.00	ppm	
NOx Sample	n/a		50.06	ppm	(Dry)
NOx Bckgrd	0.5	1	0.13	ppm	
CO2 Sample	72.7	1	0.6122	%	(Wet)
CO2 Bckgrd	8.6	1	0.0471	%	
CH4 Sample	n/a	n/a	2.18	ppm	(1.00)
CH4 Bckgrd	n/a	n/a	2.15	ppm	

Correction Factors

NOx Humidity CF:	0.989
Dry-to-Wet CF, Sample:	0.980
Dry-to-Wet CF, Bckgrd:	0.986
Dilution Factor:	21.99

Test Cycle Data

Sample Time:	1,214.20	sec		
Work:	23.95	hp-hr	17.86	kW-hr
Reference Work:	24.21	hp-hr	18.05	kW-hr
Total Volume (Vmix):	43,870.1	scf	1,242.43	scm

Corrected Concentrations

HC	2.58	ppm	
CO	42.41	ppm	
NOx	48.94	ppm	
CO2	0.5672	%	
CH4	0.13	ppm	(1.00)

Brake-Specific Emission Results

FIDHC (Cell)	0.077	g/hp-hr	0.103	g/kW-hr
CO	2.561	g/hp-hr	3.435	g/kW-hr
NOx (Cell)	4.800	g/hp-hr	6.437	g/kW-hr
Particulate	0.197	g/hp-hr	0.264	g/kW-hr
CO2	538.3	g/hp-hr	721.91	g/kW-hr
BSFC	0.376	lb/hp-hr	0.229	kg/kW-hr
NMHC	0.067	g/hp-hr	0.090	g/kW-hr
CH4	0.004	g/hp-hr	0.006	g/kW-hr

Mass Emissions

HC		1.847	grams	
CO		61.344	grams	
NOx		114.965	grams	
Particulate		4.707	grams	
CO2		12.893	kg	
CH4		0.106	grams	
Fuel	9.01 lb		4.09 kg	

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 03/18/2005	Time: 08:56	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R		HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4	Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123				

Test Numbers
Cold: ADD C1 Hot: ADD H1

Brake-Specific Emission Results

FIDHC (Cell)	0.079	g/hp-hr	0.106	g/kW-hr
CO	2.652	g/hp-hr	3.557	g/kW-hr
NOx (Cell)	4.899	g/hp-hr	6.570	g/kW-hr
Particulate	0.197	g/hp-hr	0.264	g/kW-hr
CO2	541.5	g/hp-hr	726.11	g/kW-hr
BSFC	0.379	lb/hp-hr	0.230	kg/kW-hr
NMHC	0.069	g/hp-hr	0.092	g/kW-hr
CH4	0.004	g/hp-hr	0.005	g/kW-hr
Work:	23.96	hp-hr	17.86	kW-hr
Reference Work:	24.21	hp-hr	18.05	kW-hr

Analyzed: 03/18/2005 14:13

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	ADD H2	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/18/2005	Time: 10:16	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	29.03	in Hg	98.3 kPa
Engine Inlet Air			
Temperature:	77.0	°F	25.0 °C
Dew Point:	56.2	°F	13.4 °C
Abs. Humidity:	69.6	gr/lb	9.9 g/kg
Rel. Humidity:	49	%	
Dilution Air:			
Temperature:	73.0	°F	22.8 °C
Abs. Humidity	62.8	gr/lb	9.0 g/kg
Rel. Humidity:	50	%	

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,164.5	61.30
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.63	0.05
Gas Meter 2:	3.53	0.10
Sample Rate:	1.90	0.05
Total Flow Rate:	2,166.41	61.35

Particulate Data

Filter Number:	9469.0 (pair)	
Weight Gain:	4.130	mg
Sample Multiplier:	1.140	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		6.82	ppm	
HC Bckgrd	n/a		4.90	ppm	
CO Sample	41.1	2	39.98	ppm	(Dry)
CO Bckgrd	0.3	2	0.28	ppm	
NOx Sample	n/a		50.27	ppm	(Dry)
NOx Bckgrd	0.7	1	0.18	ppm	
CO2 Sample	71.0	1	0.5901	%	(Wet)
CO2 Bckgrd	8.3	1	0.0454	%	
CH4 Sample	n/a	n/a	2.17	ppm	(1.00)
CH4 Bckgrd	n/a	n/a	22.31	ppm	

Correction Factors

NOx Humidity CF:	0.986
Dry-to-Wet CF, Sample:	0.980
Dry-to-Wet CF, Bckgrd:	0.986
Dilution Factor:	22.82

Test Cycle Data

Sample Time:	1,214.50	sec		
Work:	23.88	hp-hr	17.81	kW-hr
Reference Work:	24.21	hp-hr	18.05	kW-hr
Total Volume (Vmix):	43,851.7	scf	1,241.91	scm

Corrected Concentrations

HC	2.13	ppm	
CO	38.62	ppm	
NOx	49.11	ppm	
CO2	0.5467	%	
CH4	-19.16	ppm	(1.00)

Brake-Specific Emission Results

FIDHC (Cell)	0.064	g/hp-hr	0.086	g/kW-hr
CO	2.338	g/hp-hr	3.135	g/kW-hr
NOx (Cell)	4.817	g/hp-hr	6.460	g/kW-hr
Particulate	0.197	g/hp-hr	0.264	g/kW-hr
CO2	520.1	g/hp-hr	697.50	g/kW-hr
BSFC	0.363	lb/hp-hr	0.221	kg/kW-hr
NMHC	0.055	g/hp-hr	0.074	g/kW-hr
CH4	0.000	g/hp-hr	0.000	g/kW-hr

Mass Emissions

HC		1.525	grams	
CO		55.834	grams	
NOx		115.036	grams	
Particulate		4.708	grams	
CO2		12.421	kg	
CH4		0.000	grams	
Fuel	8.68 lb		3.93 kg	

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 03/18/2005 Time: 08:56	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4 Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123			

Test Numbers
Cold: ADD C1 Hot: ADD H2

Brake-Specific Emission Results

FIDHC (Cell)	0.068	g/hp-hr	0.091	g/kW-hr
CO	2.461	g/hp-hr	3.301	g/kW-hr
NOx (Cell)	4.914	g/hp-hr	6.589	g/kW-hr
Particulate	0.197	g/hp-hr	0.265	g/kW-hr
CO2	525.9	g/hp-hr	705.22	g/kW-hr
BSFC	0.367	lb/hp-hr	0.223	kg/kW-hr
NMHC	0.059	g/hp-hr	0.079	g/kW-hr
CH4	0.000	g/hp-hr	0.000	g/kW-hr
Work:	23.90	hp-hr	17.82	kW-hr
Reference Work:	24.21	hp-hr	18.05	kW-hr

Analyzed: 03/18/2005 14:13

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	ADD H3	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/18/2005	Time: 10:56	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	29.03	in Hg	98.3 kPa
Engine Inlet Air			
Temperature:	77.0	°F	25.0 °C
Dew Point:	55.9	°F	13.3 °C
Abs. Humidity:	68.9	gr/lb	9.8 g/kg
Rel. Humidity:	48	%	
Dilution Air:			
Temperature:	74.0	°F	23.3 °C
Abs. Humidity	65.8	gr/lb	9.4 g/kg
Rel. Humidity:	51	%	

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,164.6	61.30
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.63	0.05
Gas Meter 2:	3.56	0.10
Sample Rate:	1.93	0.05
Total Flow Rate:	2,166.51	61.36

Particulate Data

Filter Number:	9470.0-96 (pair)	
Weight Gain:	4.304	mg
Sample Multiplier:	1.122	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		7.12	ppm	
HC Bckgrd	n/a		4.80	ppm	
CO Sample	44.4	2	43.25	ppm	(Dry)
CO Bckgrd	0.1	2	0.09	ppm	
NOx Sample	n/a		50.53	ppm	(Dry)
NOx Bckgrd	0.4	1	0.10	ppm	
CO2 Sample	72.5	1	0.6095	%	(Wet)
CO2 Bckgrd	8.3	1	0.0454	%	
CH4 Sample	n/a	n/a	2.17	ppm	(1.00)
CH4 Bckgrd	n/a	n/a	2.18	ppm	

Correction Factors

NOx Humidity CF:	0.984
Dry-to-Wet CF, Sample:	0.980
Dry-to-Wet CF, Bckgrd:	0.985
Dilution Factor:	22.09

Test Cycle Data

Sample Time:	1,214.20	sec		
Work:	24.06	hp-hr	17.94	kW-hr
Reference Work:	24.21	hp-hr	18.05	kW-hr
Total Volume (Vmix):	43,843.0	scf	1,241.66	scm

Corrected Concentrations

HC	2.54	ppm	
CO	41.95	ppm	
NOx	49.40	ppm	
CO2	0.5662	%	
CH4	0.09	ppm	(1.00)

Brake-Specific Emission Results

FIDHC (Cell)	0.075	g/hp-hr	0.101	g/kW-hr
CO	2.520	g/hp-hr	3.380	g/kW-hr
NOx (Cell)	4.799	g/hp-hr	6.436	g/kW-hr
Particulate	0.201	g/hp-hr	0.269	g/kW-hr
CO2	534.5	g/hp-hr	716.79	g/kW-hr
BSFC	0.374	lb/hp-hr	0.227	kg/kW-hr
NMHC	0.065	g/hp-hr	0.088	g/kW-hr
CH4	0.003	g/hp-hr	0.004	g/kW-hr

Mass Emissions

HC		1.812	grams	
CO		60.643	grams	
NOx		115.466	grams	
Particulate		4.828	grams	
CO2		12.860	kg	
CH4		0.074	grams	
Fuel	8.99 lb		4.08 kg	

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 03/18/2005	Time: 08:56	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R		HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4	Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123				

Test Numbers
Cold: ADD C1 Hot: ADD H3

Brake-Specific Emission Results

FIDHC (Cell)	0.078	g/hp-hr	0.104	g/kW-hr
CO	2.617	g/hp-hr	3.509	g/kW-hr
NOx (Cell)	4.898	g/hp-hr	6.568	g/kW-hr
Particulate	0.200	g/hp-hr	0.269	g/kW-hr
CO2	538.2	g/hp-hr	721.71	g/kW-hr
BSFC	0.376	lb/hp-hr	0.229	kg/kW-hr
NMHC	0.068	g/hp-hr	0.091	g/kW-hr
CH4	0.003	g/hp-hr	0.004	g/kW-hr
Work:	24.05	hp-hr	17.94	kW-hr
Reference Work:	24.21	hp-hr	18.05	kW-hr

Analyzed: 03/18/2005 14:13

Southwest Research Institute - Department of Emissions Research
EPA Cold Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	ADD2 C1	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/30/2005	Time: 08:52	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	28.92	in Hg	97.9 kPa
Engine Inlet Air			
Temperature:	77.0	°F	25.0 °C
Dew Point:	57.5	°F	14.2 °C
Abs. Humidity:	73.3	gr/lb	10.5 g/kg
Rel. Humidity:	51	%	
Dilution Air:			
Temperature:	77.0	°F	25.0 °C
Abs. Humidity	86.2	gr/lb	12.3 g/kg
Rel. Humidity:	60	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.89	ppm	
HC Bckgrd	n/a		3.70	ppm	
CO Sample	55.1	2	53.90	ppm	(Dry)
CO Bckgrd	0.3	2	0.28	ppm	
NOx Sample	n/a		59.11	ppm	(Dry)
NOx Bckgrd	1.2	1	0.30	ppm	
CO2 Sample	76.3	1	0.6609	%	(Wet)
CO2 Bckgrd	8.8	1	0.0483	%	

Corrected Concentrations

HC	2.37	ppm
CO	51.92	ppm
NOx	57.32	ppm
CO2	0.6150	%

Mass Emissions

HC		1.688	grams	
CO		74.796	grams	
NOx		135.060	grams	
Particulate		5.101	grams	
CO2		13.922	kg	
Fuel	9.74 lb		4.42 kg	

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,157.6	61.10
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.62	0.05
Gas Meter 2:	3.05	0.09
Sample Rate:	1.43	0.04
Total Flow Rate:	2,158.99	61.14

Particulate Data

Filter Number:	9867.0-103 (pair)	
Weight Gain:	3.376	mg
Sample Multiplier:	1.511	

Correction Factors

NOx Humidity CF:	0.996
Dry-to-Wet CF, Sample:	0.975
Dry-to-Wet CF, Bckgrd:	0.981
Dilution Factor:	20.35

Test Cycle Data

Sample Time:	1,214.30	sec		
Work:	23.91	hp-hr	17.83	kW-hr
Reference Work:	24.12	hp-hr	17.99	kW-hr
Total Volume (Vmix):	43,694.3	scf	1,237.45	scm

Brake-Specific Emission Results

FIDHC (Cell)	0.071	g/hp-hr	0.095	g/kW-hr
CO	3.128	g/hp-hr	4.195	g/kW-hr
NOx (Cell)	5.649	g/hp-hr	7.575	g/kW-hr
Particulate	0.213	g/hp-hr	0.286	g/kW-hr
CO2	582.3	g/hp-hr	780.82	g/kW-hr
BSFC	0.407	lb/hp-hr	0.248	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	ADD2-H1	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/30/2005	Time: 09:32	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	28.93	in Hg	98.0 kPa
Engine Inlet Air			
Temperature:	79.0	°F	26.1 °C
Dew Point:	57.7	°F	14.3 °C
Abs. Humidity:	73.8	gr/lb	10.5 g/kg
Rel. Humidity:	48	%	
Dilution Air:			
Temperature:	77.0	°F	25.0 °C
Abs. Humidity	80.9	gr/lb	11.6 g/kg
Rel. Humidity:	56	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.90	ppm	
HC Bckgrd	n/a		3.80	ppm	
CO Sample	46.1	2	44.94	ppm	(Dry)
CO Bckgrd	0.3	2	0.28	ppm	
NOx Sample	n/a		50.19	ppm	(Dry)
NOx Bckgrd	1.4	1	0.35	ppm	
CO2 Sample	73.5	1	0.6228	%	(Wet)
CO2 Bckgrd	8.7	1	0.0477	%	

Corrected Concentrations

HC	2.28	ppm
CO	43.33	ppm
NOx	48.66	ppm
CO2	0.5773	%

Mass Emissions

HC		1.620	grams	
CO		62.433	grams	
NOx		114.819	grams	
Particulate		5.024	grams	
CO2		13.072	kg	
Fuel	9.14 lb		4.14 kg	

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,158.4	61.13
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.62	0.05
Gas Meter 2:	2.97	0.08
Sample Rate:	1.35	0.04
Total Flow Rate:	2,159.80	61.17

Particulate Data

Filter Number:	9868.0-104 (pair)	
Weight Gain:	3.147	mg
Sample Multiplier:	1.597	

Correction Factors

NOx Humidity CF:	0.997
Dry-to-Wet CF, Sample:	0.976
Dry-to-Wet CF, Bckgrd:	0.982
Dilution Factor:	21.62

Test Cycle Data

Sample Time:	1,214.10	sec		
Work:	23.83	hp-hr	17.77	kW-hr
Reference Work:	24.12	hp-hr	17.99	kW-hr
Total Volume (Vmix):	43,703.5	scf	1,237.71	scm

Brake-Specific Emission Results

FIDHC (Cell)	0.068	g/hp-hr	0.091	g/kW-hr
CO	2.620	g/hp-hr	3.513	g/kW-hr
NOx (Cell)	4.818	g/hp-hr	6.461	g/kW-hr
Particulate	0.211	g/hp-hr	0.283	g/kW-hr
CO2	548.5	g/hp-hr	735.61	g/kW-hr
BSFC	0.383	lb/hp-hr	0.233	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 03/30/2005 Time: 08:52	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4 Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123			

Test Numbers
Cold: ADD2 C1 Hot: ADD2-H1

Brake-Specific Emission Results

FIDHC (Cell)	0.068	g/hp-hr	0.092	g/kW-hr
CO	2.693	g/hp-hr	3.611	g/kW-hr
NOx (Cell)	4.937	g/hp-hr	6.621	g/kW-hr
Particulate	0.211	g/hp-hr	0.283	g/kW-hr
CO2	553.4	g/hp-hr	742.09	g/kW-hr
BSFC	0.387	lb/hp-hr	0.235	kg/kW-hr
Work:	23.84	hp-hr	17.78	kW-hr
Reference Work:	24.12	hp-hr	17.99	kW-hr

Analyzed: 04/05/2005 10:26

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	ADD2-H2	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/30/2005	Time: 10:12	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	28.93	in Hg	98.0 kPa
Engine Inlet Air			
Temperature:	77.0	°F	25.0 °C
Dew Point:	57.0	°F	13.9 °C
Abs. Humidity:	71.9	gr/lb	10.3 g/kg
Rel. Humidity:	50	%	
Dilution Air:			
Temperature:	78.0	°F	25.6 °C
Abs. Humidity	89.8	gr/lb	12.8 g/kg
Rel. Humidity:	60	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		6.29	ppm	
HC Bckgrd	n/a		4.70	ppm	
CO Sample	45.6	2	44.44	ppm	(Dry)
CO Bckgrd	0.3	2	0.28	ppm	
NOx Sample	n/a		51.20	ppm	(Dry)
NOx Bckgrd	1.3	1	0.33	ppm	
CO2 Sample	73.0	1	0.6161	%	(Wet)
CO2 Bckgrd	8.6	1	0.0471	%	

Corrected Concentrations

HC	1.81	ppm
CO	42.79	ppm
NOx	49.56	ppm
CO2	0.5712	%

Mass Emissions

HC		1.281	grams	
CO		61.490	grams	
NOx		116.075	grams	
Particulate		5.152	grams	
CO2		12.897	kg	
Fuel	9.01 lb		4.09	kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,152.1	60.95
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.62	0.05
Gas Meter 2:	3.02	0.09
Sample Rate:	1.40	0.04
Total Flow Rate:	2,153.52	60.99

Particulate Data

Filter Number:	9869.0-105 (pair)	
Weight Gain:	3.348	mg
Sample Multiplier:	1.539	

Correction Factors

NOx Humidity CF:	0.992
Dry-to-Wet CF, Sample:	0.974
Dry-to-Wet CF, Bckgrd:	0.980
Dilution Factor:	21.85

Test Cycle Data

Sample Time:	1,214.30	sec		
Work:	23.80	hp-hr	17.75	kW-hr
Reference Work:	24.12	hp-hr	17.99	kW-hr
Total Volume (Vmix):	43,583.6	scf	1,234.31	scm

Brake-Specific Emission Results

FIDHC (Cell)	0.054	g/hp-hr	0.072	g/kW-hr
CO	2.584	g/hp-hr	3.465	g/kW-hr
NOx (Cell)	4.877	g/hp-hr	6.540	g/kW-hr
Particulate	0.216	g/hp-hr	0.290	g/kW-hr
CO2	541.9	g/hp-hr	726.69	g/kW-hr
BSFC	0.379	lb/hp-hr	0.230	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 03/30/2005 Time: 08:52	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4 Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123			

Test Numbers
Cold: ADD2 C1 Hot: ADD2-H2

Brake-Specific Emission Results

FIDHC (Cell)	0.056	g/hp-hr	0.075	g/kW-hr
CO	2.662	g/hp-hr	3.569	g/kW-hr
NOx (Cell)	4.988	g/hp-hr	6.689	g/kW-hr
Particulate	0.216	g/hp-hr	0.290	g/kW-hr
CO2	547.7	g/hp-hr	734.45	g/kW-hr
BSFC	0.383	lb/hp-hr	0.233	kg/kW-hr
Work:	23.82	hp-hr	17.76	kW-hr
Reference Work:	24.12	hp-hr	17.99	kW-hr

Analyzed: 04/05/2005 10:26

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	ADD2-H3	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/30/2005	Time: 10:52	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	28.93	in Hg	98.0 kPa
Engine Inlet Air			
Temperature:	77.0	°F	25.0 °C
Dew Point:	55.5	°F	13.1 °C
Abs. Humidity:	68.1	gr/lb	9.7 g/kg
Rel. Humidity:	47	%	
Dilution Air:			
Temperature:	78.0	°F	25.6 °C
Abs. Humidity	74.1	gr/lb	10.6 g/kg
Rel. Humidity:	50	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		6.50	ppm	
HC Bckgrd	n/a		3.80	ppm	
CO Sample	45.1	2	43.95	ppm	(Dry)
CO Bckgrd	0.4	2	0.37	ppm	
NOx Sample	n/a		50.74	ppm	(Dry)
NOx Bckgrd	0.9	1	0.23	ppm	
CO2 Sample	73.8	1	0.6268	%	(Wet)
CO2 Bckgrd	7.9	1	0.0431	%	

Corrected Concentrations

HC	2.88	ppm
CO	42.37	ppm
NOx	49.38	ppm
CO2	0.5857	%

Mass Emissions

HC		2.046	grams	
CO		60.988	grams	
NOx		114.705	grams	
Particulate		4.952	grams	
CO2		13.248	kg	
Fuel	9.26 lb		4.20 kg	

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,155.2	61.04
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.62	0.05
Gas Meter 2:	3.02	0.09
Sample Rate:	1.40	0.04
Total Flow Rate:	2,156.65	61.08

Particulate Data

Filter Number:	9907.0-106 (pair)	
Weight Gain:	3.224	mg
Sample Multiplier:	1.536	

Correction Factors

NOx Humidity CF:	0.982
Dry-to-Wet CF, Sample:	0.978
Dry-to-Wet CF, Bckgrd:	0.983
Dilution Factor:	21.48

Test Cycle Data

Sample Time:	1,214.60	sec		
Work:	23.82	hp-hr	17.76	kW-hr
Reference Work:	24.12	hp-hr	17.99	kW-hr
Total Volume (Vmix):	43,657.7	scf	1,236.41	scm

Brake-Specific Emission Results

FIDHC (Cell)	0.086	g/hp-hr	0.115	g/kW-hr
CO	2.560	g/hp-hr	3.433	g/kW-hr
NOx (Cell)	4.815	g/hp-hr	6.458	g/kW-hr
Particulate	0.208	g/hp-hr	0.279	g/kW-hr
CO2	556.2	g/hp-hr	745.85	g/kW-hr
BSFC	0.389	lb/hp-hr	0.236	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 03/30/2005	Time: 08:52	, EM-5476-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R		HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4	Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123				

Test Numbers
Cold: ADD2 C1 Hot: ADD2-H3

Brake-Specific Emission Results

FIDHC (Cell)	0.084	g/hp-hr	0.112	g/kW-hr
CO	2.642	g/hp-hr	3.543	g/kW-hr
NOx (Cell)	4.935	g/hp-hr	6.618	g/kW-hr
Particulate	0.209	g/hp-hr	0.280	g/kW-hr
CO2	559.9	g/hp-hr	750.86	g/kW-hr
BSFC	0.391	lb/hp-hr	0.238	kg/kW-hr
Work:	23.83	hp-hr	17.77	kW-hr
Reference Work:	24.12	hp-hr	17.99	kW-hr

Analyzed: 04/05/2005 10:26

Southwest Research Institute - Department of Emissions Research
EPA Cold Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	BASE-C2		DIESEL 2D, EM-5402-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/11/2005	Time: 01:35	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	28.95	in Hg	98.0 kPa
Engine Inlet Air			
Temperature:	77.0	°F	25.0 °C
Dew Point:	56.9	°F	13.8 °C
Abs. Humidity:	71.6	gr/lb	10.2 g/kg
Rel. Humidity:	50	%	
Dilution Air:			
Temperature:	78.0	°F	25.6 °C
Abs. Humidity	54.6	gr/lb	7.8 g/kg
Rel. Humidity:	37	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.68	ppm	
HC Bckgrd	n/a		3.70	ppm	
CO Sample	56.8	2	55.60	ppm	(Dry)
CO Bckgrd	0.4	2	0.37	ppm	
NOx Sample	n/a		58.81	ppm	(Dry)
NOx Bckgrd	0.7	1	0.18	ppm	
CO2 Sample	74.3	1	0.6335	%	(Wet)
CO2 Bckgrd	7.9	1	0.0431	%	

Corrected Concentrations

HC	2.15	ppm
CO	53.92	ppm
NOx	57.57	ppm
CO2	0.5924	%

Mass Emissions

HC		1.527	grams	
CO		77.363	grams	
NOx		134.523	grams	
Particulate		5.146	grams	
CO2		13.358	kg	
Fuel	9.35 lb		4.24	kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,149.0	60.86
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.62	0.05
Gas Meter 2:	3.03	0.09
Sample Rate:	1.41	0.04
Total Flow Rate:	2,150.40	60.90

Particulate Data

Filter Number:	1285.0-108 (pair)	
Weight Gain:	3.374	mg
Sample Multiplier:	1.525	

Correction Factors

NOx Humidity CF:	0.991
Dry-to-Wet CF, Sample:	0.982
Dry-to-Wet CF, Bckgrd:	0.988
Dilution Factor:	21.22

Test Cycle Data

Sample Time:	1,214.30	sec		
Work:	23.56	hp-hr	17.57	kW-hr
Reference Work:	24.29	hp-hr	18.11	kW-hr
Total Volume (Vmix):	43,520.5	scf	1,232.53	scm

Brake-Specific Emission Results

BSHC (Cell)	0.065	g/hp-hr	0.087	g/kW-hr
CO	3.284	g/hp-hr	4.403	g/kW-hr
NOx (Cell)	5.710	g/hp-hr	7.657	g/kW-hr
Particulate	0.218	g/hp-hr	0.293	g/kW-hr
CO2	567.0	g/hp-hr	760.34	g/kW-hr
BSFC	0.397	lb/hp-hr	0.241	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	BASE H4	DIESEL 2D, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/11/2005	Time: 02:15	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	28.94	in Hg	98.0 kPa
Engine Inlet Air			
Temperature:	77.0	°F	25.0 °C
Dew Point:	54.2	°F	12.3 °C
Abs. Humidity:	64.9	gr/lb	9.3 g/kg
Rel. Humidity:	45	%	
Dilution Air:			
Temperature:	79.0	°F	26.1 °C
Abs. Humidity	44.0	gr/lb	6.3 g/kg
Rel. Humidity:	29	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.18	ppm	
HC Bckgrd	n/a		3.30	ppm	
CO Sample	47.3	2	46.13	ppm	(Dry)
CO Bckgrd	0.6	2	0.56	ppm	
NOx Sample	n/a		51.68	ppm	(Dry)
NOx Bckgrd	0.6	1	0.15	ppm	
CO2 Sample	72.8	1	0.6135	%	(Wet)
CO2 Bckgrd	7.8	1	0.0425	%	

Corrected Concentrations

HC	2.03	ppm
CO	44.63	ppm
NOx	50.73	ppm
CO2	0.5729	%

Mass Emissions

HC		1.441	grams	
CO		64.108	grams	
NOx		116.634	grams	
Particulate		5.326	grams	
CO2		12.932	kg	
Fuel	9.04 lb		4.10	kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,151.5	60.93
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.62	0.05
Gas Meter 2:	3.04	0.09
Sample Rate:	1.42	0.04
Total Flow Rate:	2,152.88	60.97

Particulate Data

Filter Number:	1286.0-109 (pair)	
Weight Gain:	3.518	mg
Sample Multiplier:	1.514	

Correction Factors

NOx Humidity CF:	0.974
Dry-to-Wet CF, Sample:	0.984
Dry-to-Wet CF, Bckgrd:	0.990
Dilution Factor:	21.94

Test Cycle Data

Sample Time:	1,214.20	sec		
Work:	23.62	hp-hr	17.61	kW-hr
Reference Work:	24.29	hp-hr	18.11	kW-hr
Total Volume (Vmix):	43,567.0	scf	1,233.84	scm

Brake-Specific Emission Results

BSHC (Cell)	0.061	g/hp-hr	0.082	g/kW-hr
CO	2.714	g/hp-hr	3.640	g/kW-hr
NOx (Cell)	4.938	g/hp-hr	6.622	g/kW-hr
Particulate	0.225	g/hp-hr	0.302	g/kW-hr
CO2	547.5	g/hp-hr	734.23	g/kW-hr
BSFC	0.383	lb/hp-hr	0.233	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 04/11/2005 Time: 01:35	DIESEL 2D, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4 Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123			

Test Numbers
Cold: BASE-C2 Hot: BASE H4

Brake-Specific Emission Results

BSHC (Cell)	0.062	g/hp-hr	0.083	g/kW-hr
CO	2.795	g/hp-hr	3.749	g/kW-hr
NOx (Cell)	5.048	g/hp-hr	6.769	g/kW-hr
Particulate	0.224	g/hp-hr	0.301	g/kW-hr
CO2	550.3	g/hp-hr	737.95	g/kW-hr
BSFC	0.385	lb/hp-hr	0.234	kg/kW-hr
Work:	23.61	hp-hr	17.61	kW-hr
Reference Work:	24.29	hp-hr	18.11	kW-hr

Analyzed: 04/11/2005 15:36

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	BASE H5	DIESEL 2D, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/11/2005	Time: 02:55	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	28.92	in Hg	97.9 kPa
Engine Inlet Air			
Temperature:	77.0	°F	25.0 °C
Dew Point:	55.0	°F	12.8 °C
Abs. Humidity:	66.9	gr/lb	9.6 g/kg
Rel. Humidity:	47	%	
Dilution Air:			
Temperature:	79.0	°F	26.1 °C
Abs. Humidity	44.0	gr/lb	6.3 g/kg
Rel. Humidity:	29	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.09	ppm	
HC Bckgrd	n/a		3.00	ppm	
CO Sample	47.0	2	45.83	ppm	(Dry)
CO Bckgrd	0.7	2	0.66	ppm	
NOx Sample	n/a		51.73	ppm	(Dry)
NOx Bckgrd	0.6	1	0.15	ppm	
CO2 Sample	72.6	1	0.6109	%	(Wet)
CO2 Bckgrd	7.6	1	0.0414	%	

Corrected Concentrations

HC	2.23	ppm
CO	44.24	ppm
NOx	50.78	ppm
CO2	0.5714	%

Mass Emissions

HC		1.579	grams	
CO		63.546	grams	
NOx		117.328	grams	
Particulate		4.798	grams	
CO2		12.896	kg	
Fuel	9.01 lb		4.09	kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,149.8	60.88
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.61	0.05
Gas Meter 2:	3.15	0.09
Sample Rate:	1.54	0.04
Total Flow Rate:	2,151.38	60.93

Particulate Data

Filter Number:	1287.0-110 (pair)	
Weight Gain:	3.433	mg
Sample Multiplier:	1.398	

Correction Factors

NOx Humidity CF:	0.979
Dry-to-Wet CF, Sample:	0.984
Dry-to-Wet CF, Bckgrd:	0.990
Dilution Factor:	22.03

Test Cycle Data

Sample Time:	1,214.90	sec		
Work:	23.71	hp-hr	17.68	kW-hr
Reference Work:	24.29	hp-hr	18.11	kW-hr
Total Volume (Vmix):	43,561.8	scf	1,233.70	scm

Brake-Specific Emission Results

BSHC (Cell)	0.067	g/hp-hr	0.089	g/kW-hr
CO	2.680	g/hp-hr	3.594	g/kW-hr
NOx (Cell)	4.948	g/hp-hr	6.636	g/kW-hr
Particulate	0.202	g/hp-hr	0.271	g/kW-hr
CO2	543.9	g/hp-hr	729.37	g/kW-hr
BSFC	0.380	lb/hp-hr	0.231	kg/kW-hr

Analyzed: 04/12/2005 08:15

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 04/11/2005 Time: 01:35	DIESEL 2D, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4 Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123			

Test Numbers
Cold: BASE-C2 Hot: BASE H5

Brake-Specific Emission Results

BSHC (Cell)	0.066	g/hp-hr	0.089	g/kW-hr
CO	2.766	g/hp-hr	3.709	g/kW-hr
NOx (Cell)	5.057	g/hp-hr	6.781	g/kW-hr
Particulate	0.205	g/hp-hr	0.274	g/kW-hr
CO2	547.2	g/hp-hr	733.77	g/kW-hr
BSFC	0.383	lb/hp-hr	0.233	kg/kW-hr
Work:	23.69	hp-hr	17.66	kW-hr
Reference Work:	24.29	hp-hr	18.11	kW-hr

Analyzed: 04/11/2005 15:36

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Test No.:	BASE H6	DIESEL 2D, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/11/2005	Time: 03:35	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT:	4.12-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123	Cell: 4	Bag Cart: 1		

Ambient/Test Cell Conditions

Barometer:	28.91	in Hg	97.9 kPa
Engine Inlet Air			
Temperature:	78.0	°F	25.6 °C
Dew Point:	54.3	°F	12.4 °C
Abs. Humidity:	65.2	gr/lb	9.3 g/kg
Rel. Humidity:	44	%	
Dilution Air:			
Temperature:	80.0	°F	26.7 °C
Abs. Humidity	46.9	gr/lb	6.7 g/kg
Rel. Humidity:	30	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.30	ppm	
HC Bckgrd	n/a		3.50	ppm	
CO Sample	47.0	2	45.83	ppm	(Dry)
CO Bckgrd	0.7	2	0.66	ppm	
NOx Sample	n/a		51.85	ppm	(Dry)
NOx Bckgrd	0.5	1	0.13	ppm	
CO2 Sample	73.5	1	0.6228	%	(Wet)
CO2 Bckgrd	7.6	1	0.0414	%	

Corrected Concentrations

HC	1.96	ppm
CO	44.22	ppm
NOx	50.88	ppm
CO2	0.5833	%

Mass Emissions

HC	1.391	grams		
CO	63.466	grams		
NOx	116.965	grams		
Particulate	5.279	grams		
CO2	13.155	kg		
Fuel	9.19	lb	4.17	kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	2,149.1	60.86
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.62	0.05
Gas Meter 2:	2.99	0.08
Sample Rate:	1.37	0.04
Total Flow Rate:	2,150.47	60.90

Particulate Data

Filter Number:	1288.0-111 (pair)	
Weight Gain:	3.370	mg
Sample Multiplier:	1.566	

Correction Factors

NOx Humidity CF:	0.975
Dry-to-Wet CF, Sample:	0.984
Dry-to-Wet CF, Bckgrd:	0.989
Dilution Factor:	21.61

Test Cycle Data

Sample Time:	1,214.50	sec		
Work:	23.81	hp-hr	17.76	kW-hr
Reference Work:	24.29	hp-hr	18.11	kW-hr
Total Volume (Vmix):	43,529.0	scf	1,232.77	scm

Brake-Specific Emission Results

BSHC (Cell)	0.058	g/hp-hr	0.078	g/kW-hr
CO	2.666	g/hp-hr	3.575	g/kW-hr
NOx (Cell)	4.912	g/hp-hr	6.588	g/kW-hr
Particulate	0.222	g/hp-hr	0.297	g/kW-hr
CO2	552.5	g/hp-hr	740.92	g/kW-hr
BSFC	0.386	lb/hp-hr	0.235	kg/kW-hr

Analyzed: 04/12/2005 08:25

Southwest Research Institute - Department of Emissions Research
Composite Transient Emission Test Results
Project No. 3-11251-001

Engine Model:	1991 Detroit Diesel S60	Date: 04/11/2005 Time: 01:35	DIESEL 2D, EM-5402-F	
Engine Desc.:	12.7 L (775 CID) 6	Program HDT: 4.12-R	HCR: 1.812	FID Resp: 1.00
Engine Cycle:	Diesel	Cell: 4 Bag Cart: 1	H= 0.132 C= 0.868 O= 0.000 X= 0.000	
Engine S/N:	06RE001123			

Test Numbers
Cold: BASE-C2 Hot: BASE H6

Brake-Specific Emission Results

BSHC (Cell)	0.059	g/hp-hr	0.080	g/kW-hr
CO	2.753	g/hp-hr	3.692	g/kW-hr
NOx (Cell)	5.025	g/hp-hr	6.739	g/kW-hr
Particulate	0.221	g/hp-hr	0.297	g/kW-hr
CO2	554.6	g/hp-hr	743.67	g/kW-hr
BSFC	0.388	lb/hp-hr	0.236	kg/kW-hr
Work:	23.77	hp-hr	17.73	kW-hr
Reference Work:	24.29	hp-hr	18.11	kW-hr

Analyzed: 04/11/2005 15:36

APPENDIX B

HYDROCARBON SPECIATION DATA

TABLE B-1. COMPARISON OF HYDROCARBON SPECIATION DATA FOR BOTH FUELS

	mg/hp-hr				mg/hp-hr			
COMPOUND	Base C1	Base H1	Base H2	Base H3	Add C1	Add H1	Add H2	Add H3
METHANE	1.99		3.49		0.46	4.43		3.08
ETHANE	0.29	0.20	0.26	0.25		0.05		0.05
ETHYLENE	16.21	13.68	12.90	11.14	17.60	14.40	12.30	13.86
PROPANE			0.38	0.02				
PROPYLENE								
ACETYLENE	3.44	2.76	2.61	2.23	3.30	2.86	2.57	2.72
PROPADIENE								
BUTANE								
TRANS-2-BUTENE	0.22	0.25	0.22	0.19	0.25	0.23	0.23	0.26
1-BUTENE	1.06	1.10	1.07	0.91	1.30	1.13	0.97	1.14
2-METHYLPROPENE (ISOBUTYLENE)	0.95	1.01	0.98	0.85	1.25	1.14	1.02	1.11
2,2-DIMETHYLPROPANE (NEOPENTANE)	0.13	0.07	0.23		0.15	0.13	0.49	0.56
PROPYNE								
1,3-BUTADIENE	1.20	1.35	1.29	1.09	1.71	1.54	1.36	1.53
2-METHYLPROPANE (ISOBUTANE)			0.26		0.02		0.11	0.15
1-BUTYNE								
METHANOL								
CIS-2-BUTENE								
3-METHYL-1-BUTENE								
ETHANOL								
2-METHYLBUTANE (ISOPENTANE)	0.19				0.20	0.18		0.18
2-BUTYNE								
1-PENTENE	0.21							
2-METHYL-1-BUTENE	0.17							
PENTANE	0.34							
UNIDENTIFIED C5 OLEFINS								
2-METHYL-1,3-BUTADIENE		0.24	0.17	0.21	0.26	0.19	0.16	0.20
TRANS-2-PENTENE								
3,3-DIMETHYL-1-BUTENE								
CIS-2-PENTENE								
2-METHYL-2-BUTENE	0.27					0.18	0.21	0.18
TERT-BUTANOL								
CYCLOPENTADIENE								
2,2-DIMETHYLBUTANE								
CYCLOPENTENE								
4-METHYL-1-PENTENE	0.19		0.19			0.23		0.21
3-METHYL-1-PENTENE								
CYCLOPENTANE		0.27	0.21		0.27	0.24	0.21	
2,3-DIMETHYLBUTANE								
MTBE								
4-METHYL-CIS-2-PENTENE								
2-METHYLPENTANE				0.19			0.19	
4-METHYL-TRANS-2-PENTENE								

TABLE B-1 (CONT'D.). COMPARISON OF HYDROCARBON SPECIATION DATA FOR BOTH FUELS

3-METHYLPENTANE	1.18			1.07	0.69	1.16		
2-METHYL-1-PENTENE	0.43	0.50	0.46	0.44	0.27	0.45	0.40	0.45
1-HEXENE	0.43	0.50	0.46	0.44	0.27	0.45	0.40	0.45
HEXANE	0.21				0.24	0.23	0.32	0.34
UNIDENTIFIED C6		0.50	0.26				0.18	0.42
TRANS-3-HEXENE								
CIS-3-HEXENE								
DI-ISOPROPYL ETHER								
TRANS-2-HEXENE								
3-METHYL-TRANS-2-PENTENE								
2-METHYL-2-PENTENE								
3-METHYLCYCLOPENTENE								
CIS-2-HEXENE								
ETBE								
3-METHYL-CIS-2-PENTENE								
2,2-DIMETHYLPENTANE, NOTE A								
METHYLCYCLOPENTANE, NOTE A								
2,4-DIMETHYLPENTANE								
2,2,3-TRIMETHYLBUTANE								
3,4-DIMETHYL-1-PENTENE								
1-METHYLCYCLOPENTENE								
BENZENE	1.22	1.05	0.92	0.81	1.35	1.05	0.83	0.78
3-METHYL-1-HEXENE								
3,3-DIMETHYLPENTANE								
CYCLOHEXANE								
2-METHYLHEXANE								
2,3-DIMETHYLPENTANE	0.05	0.02	0.01	0.00		0.11	0.05	0.10
1,1-DIMETHYLCYCLOPENTANE								
TERT-AMYL METHYL ETHER								
CYCLOHEXENE								
3-METHYLHEXANE								
CIS-1,3-DIMETHYLCYCLOPENTANE	0.25	0.26	0.25	0.23	0.23	0.20		0.21
3-ETHYLPENTANE								
TRANS-1,2-DIMETHYLCYCLOPENTANE								
TRANS-1,3-DIMETHYLCYCLOPENTANE								
1-HEPTENE								
2,2,4-TRIMETHYLPENTANE	trace	trace	trace	trace	0.23	0.26	0.20	0.40
2-METHYL-1-HEXENE								
TRANS-3-HEPTENE								
HEPTANE	trace	trace	trace	trace	0.18	0.18	0.16	0.17
CIS-3-HEPTENE								
UNIDENTIFIED C7								
2-METHYL-2-HEXENE								
3-METHYL-TRANS-3-HEXENE								
TRANS-2-HEPTENE								
3-ETHYL-CIS-2-PENTENE								
2,4,4-TRIMETHYL-1-PENTENE								

TABLE B-1 (CONT'D.). COMPARISON OF HYDROCARBON SPECIATION DATA FOR BOTH FUELS

2,3-DIMETHYL-2-PENTENE								
CIS-2-HEPTENE								
METHYLCYCLOHEXANE	0.20	0.20	0.24	0.20	0.20	0.22		0.22
CIS-1,2-DIMETHYLCYCLOPENTANE								
2,2-DIMETHYLHEXANE								
1,1,3-TRIMETHYLCYCLOPENTANE								
2,4,4-TRIMETHYL-2-PENTENE								
2,2,3-TRIMETHYLPENTANE								
2,5-DIMETHYLHEXANE								
ETHYLCYCLOPENTANE								
2,4-DIMETHYLHEXANE				0.20		0.26		0.27
1-TRANS-2-CIS-4-TRIMETHYLCYCLOPENTANE								
3,3-DIMETHYLHEXANE								
1-TRANS-2-CIS-3-TRIMETHYLCYCLOPENTANE								
2,3,4-TRIMETHYLPENTANE		0.06			0.16		0.16	0.21
2,3,3-TRIMETHYLPENTANE								
TOLUENE	0.82	0.64	0.42	0.21	1.45	0.55	0.43	0.67
2,3-DIMETHYLHEXANE								
1,1,2-TRIMETHYLCYCLOPENTANE								
2-METHYLHEPTANE								
3,4-DIMETHYLHEXANE, NOTE B								
4-METHYLHEPTANE								
3-METHYLHEPTANE								
1-CIS,2-TRANS,3-TRIMETHYLCYCLOPENTANE								
CIS-1,3-DIMETHYLCYCLOHEXANE								
TRANS-1,4-DIMETHYLCYCLOHEXANE								
3-ETHYLHEXANE	0.22							
2,2,5-TRIMETHYLHEXANE								
TRANS-1-METHYL-3-ETHYLCYCLOPENTANE								
CIS-1-METHYL-3-ETHYLCYCLOPENTANE	0.26	0.24	0.24	0.25	0.23	0.22	0.18	0.24
1,1-DIMETHYLCYCLOHEXANE								
TRANS-1-METHYL-2-ETHYLCYCLOPENTANE								
1-METHYL-1-ETHYL-CYCLOPENTANE								
2,4,4-TRIMETHYLHEXANE								
2,2,4-TRIMETHYLHEXANE								
TRANS-1,2-DIMETHYLCYCLOHEXANE								
1-OCTENE								
TRANS-4-OCTENE								
OCTANE	0.29	0.26	0.21	0.36	0.18		0.18	0.18
UNIDENTIFIED C8	0.21				0.26			
TRANS-2-OCTENE								
TRANS-1,3-DIMETHYLCYCLOHEXANE, NOTE C								
CIS-2-OCTENE								
ISOPROPYLCYCLOPENTANE								
2,2-DIMETHYLHEPTANE								
2,3,5-TRIMETHYLHEXANE								

TABLE B-1 (CONT'D.). COMPARISON OF HYDROCARBON SPECIATION DATA FOR BOTH FUELS

CIS-1-METHYL-2-ETHYLCYCLOPENTANE								
2,4-DIMETHYLHEPTANE								
4,4-DIMETHYLHEPTANE								
CIS-1,2-DIMETHYLCYCLOHEXANE								
ETHYLCYCLOHEXANE								
2,6-DIMETHYLHEPTANE, NOTE D	0.21	0.33	0.23	0.24	0.30	0.29	0.19	0.27
1,1,3-TRIMETHYLCYCLOHEXANE								
2,5-DIMETHYLHEPTANE, NOTE E								
3,3-DIMETHYLHEPTANE								
3,5-DIMETHYLHEPTANE, NOTE E								
ETHYLBENZENE	0.22	0.28	0.23		0.31	0.30		0.24
2,3,4-TRIMETHYLHEXANE								
2,3-DIMETHYLHEPTANE								
m-& p-XYLENE		0.21			0.36	0.35		0.16
4-METHYLOCTANE								
3,4-DIMETHYLHEPTANE								
4-ETHYLHEPTANE								
2-METHYLOCTANE								
3-METHYLOCTANE								
STYRENE								
o-XYLENE								
1-NONENE								
TRANS-3-NONENE								
CIS-3-NONENE								
NONANE								
TRANS-2-NONENE								
ISOPROPYLBENZENE (CUMENE)								
2,2-DIMETHYLOCTANE								
2,4-DIMETHYLOCTANE								
n-PROPYLBENZENE								
1-METHYL-3-ETHYLBENZENE								
1-METHYL-4-ETHYLBENZENE								
1,3,5-TRIMETHYLBENZENE								
1-METHYL-2-ETHYLBENZENE								
1,2,4-TRIMETHYLBENZENE								
TERT-BUTYLBENZENE								
1-DECENE								
DECANE, NOTE F								
ISOBUTYLBENZENE, NOTE F								
1,3,-DIMETHYL-5-ETHYLBENZENE								
METHYLPROPYLBENZENE (sec butylbenzene)								
1-METHYL-3-ISOPROPYLBENZENE								
1,2,3-TRIMETHYLBENZENE								
1-METHYL-4-ISOPROPYLBENZENE								
INDAN								
1-METHYL-2-ISOPROPYLBENZENE								
1,3-DIETHYLBENZENE								
1,4-DIETHYLBENZENE								

TABLE B-1 (CONT'D.). COMPARISON OF HYDROCARBON SPECIATION DATA FOR BOTH FUELS

1-METHYL-3-N-PROPYLBENZENE								
1-METHYL-4-N-PROPYLBENZENE, NOTE G								
1,2 DIETHYLBENZENE								
1-METHYL-2-N-PROPYLBENZENE								
1,4-DIMETHYL-2-ETHYLBENZENE								
1,3-DIMETHYL-4-ETHYLBENZENE								
1,2-DIMETHYL-4-ETHYLBENZENE								
1,3-DIMETHYL-2-ETHYLBENZENE								
UNDECANE								
1,2-DIMETHYL-3-ETHYLBENZENE								
1,2,4,5-TETRAMETHYLBENZENE								
2-METHYLBUTYLBENZENE (sec AMYLBENZENE)								
3,4 DIMETHYLCUMENE								
1,2,3,5-TETRAMETHYLBENZENE								
TERT-1-BUT-2-METHYLBENZENE								
1,2,3,4-TETRAMETHYLBENZENE								
N-PENT-BENZENE								
TERT-1-BUT-3,5-DIMETHYLBENZENE								
TERT-1-BUTYL-4-ETHYLBENZENE								
NAPHTHALENE								
DODECANE								
1,3,5-TRIETHYLBENZENE								
1,2,4-TRIETHYLBENZENE								
HEXYLBENZENE								
UNIDENTIFIED C9-C12+								
FORMALDEHYDE	11.67	10.25	9.29	10.37	18.04	12.70	12.40	12.21
ACETALDEHYDE	4.49	4.12	3.80	4.17	6.17	4.32	4.32	4.23
ACROLEIN	0.35	0.32	0.35	0.38	1.16	0.89	0.88	0.85
ACETONE	0.28							
PROPIONALDEHYDE	2.56	2.53	1.98	2.28	2.41	2.04	2.07	1.86
CROTONALDEHYDE	1.58	1.58	1.40	1.23	2.91	1.92	1.69	1.82
n-BUTYRALDEHYDE, NOTE H	0.48	0.56	0.25	0.29	0.35	0.20	0.18	0.11
METHYL ETHYL KETONE, NOTE H	0.48	0.56	0.25	0.29	0.35	0.20	0.18	0.11
BENZALDEHYDE	0.47	0.98	0.25	0.36	0.23	0.29	0.28	0.21
ISOVALERALDEHYDE	0.25		0.23	0.24	0.34	0.30	0.18	0.29
VALERALDEHYDE	0.44		0.40	0.41	0.49	0.42	0.21	0.13
O-TOLUALDEHYDE	0.27		0.18	0.30	0.41	0.46	0.32	0.23
M/P-TOLUALDEHYDE	1.04	0.60	0.80	1.01	0.42	1.29	0.82	0.92
HEXANALDEHYDE	0.11		0.10	0.13	0.16	0.21	0.13	0.10
DIMETHYLBENZALDEHYDE	0.16			0.26	0.37	0.34	0.23	0.11
SUMMED SPECIATED VALUES								

A - 2,2-Dimethylpentane and methylcyclopentane co-elute. GC peak area split equally between the two compounds.
B - 3-Methyl-3-ethyl-pentane co-elutes with reported compound. Not reported separately.
C - Cis-1,4-Dimethylcyclohexane co-elutes with reported compound. Not reported separately.
D - Propylcyclopentane co-elutes with reported compound. Not reported separately.
E - 2,5-Dimethylheptane and 3,5-dimethylheptane co-elute. GC peak area split equally between the two compounds.
F - Decane and isobutylbenzene co-elute. GC peak area split equally between the two compounds.
G - n-Butylbenzene co-elutes with reported compound. Not reported separately.
H - n-butyraldehyde and methyl ethyl ketone co-elute. LC peak area split equally between the two compounds