EPA-AA-TETSB-94-01

TECHNICAL REPORT

HEAVY-DUTY ENGINE TESTING REPORT NON-ROAD ENGINE CONFIGURATIONS TEST RESULTS - 1991

by

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July, 1992

NOTICE

Regulation Development and Support Division
Office of Mobile Sources
Office of Air and Radiation
U.S. Environmental Protection Agency

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1. Executive Summary

This report contains emission test results from three heavy-duty diesel engines. Two 140 hp John Deere 6068 engines (one 1990 model year non-road engine and its prototype "on-highway" counterpart) and one 1991 model year, 130 hp Ford New Holland engine were tested. Emission testing included EPA Heavy-Duty Federal Test Procedure (HD-FTP) transient emission tests and 8-mode steady-state tests. Each engine was tested for emissions of HC, CO, NO_x, and Particulate Matter (PM). A summary of the average test results is given below in Tables 1.1 and 1.2.

Table 1.1
Emissions Summary for John Deere 6068 Engines

John Deere 6068T Non-Road Engine

	HC (g/hp-hr)	CO (g/hp-hr)	NO_x (g/hp-hr)	PM (g/hp-hr)
HD-FTP, Transient	0.858	3.606	10.808	0.405
8-Mode, Steady-State	0.427	3.144	11.758	0.422

John Deere 6068H Prototype "On-Highway" Engine

	HC (g/hp-hr)	CO (g/hp-hr)	NO_x (g/hp-hr)	PM (g/hp-hr)
HD-FTP, Transient	0.730	2.573	6.091	0.343
8-Mode, Steady-State	0.312	1.213	6.066	0.180

Table 1.2
Emissions Summary for Ford New Holland Engine

Ford New Holland Production Engine

	HC (g/hp-hr)	CO (g/hp-hr)	NO_x (g/hp-hr)	PM (g/hp-hr)
HD-FTP, Transient	2.571	6.267	9.656	1.031
8-Mode, Steady-State	0.947	6.395	7.601	1.020

The data from the John Deere engines showed similar NO_x levels for the steady-state and transient tests. This was the case for both the non-road engine and the "on-highway" version, the latter of which incorporates some moderate NO_x control technology (primarily an intercooler and timing adjustments). However, this trend of equivalency between transient and steady-state NO_x results was not evident in the Ford New Holland data. Additionally, for the emission data from these three engines, there is little correlation between the 8-mode steady-state test and the HD-FTP transient test for HC, CO, or PM.

2. Introduction

In 1990, the US Congress passed, and the president signed into law, a revised Clean Air Act. One element of the 1990 Clean Air Act is a requirement to regulate non-road engines if they are found to be significant contributors to urban air pollution. As part of the resultant regulatory development program, EPA developed a data collection program that included an evaluation of the relationship between transient and 8-mode emission data on current and potential future non-road engines. Of particular interest was the ability of the 8-mode test to predict transient NO_x emissions. The program was also designed to add to the baseline data base of 8-mode emission results from engines employing 1990 type on-road technology.

Test results for three engines are presented in this report. Two of the engines that were tested were supplied by John Deere and one was supplied by Ford New Holland. The John Deere engine pair consisted of a production non-road engine and an engine modified to a lower NO_x configuration by applying on-road technology. The Ford New Holland engine was a production non-road engine.

3. Engines

Table 3.1 summarizes the specifications for the three engines which were used in this program. The 1990 model year John Deere 6068's were turbocharged in-line, 6-cylinder, 6.8 L displacement heavy-duty diesel engines. Rated and peak torque speeds for both of these direct injection engines were 2200 and 1300 RPM, respectively. Rated horsepower for the production engine was 139 hp and for the prototype engine was 147 hp. The prototype engine was modified for NO_x control primarily through timing retard and an air-to-water intercooler which simulated an air-to-air intercooler. The intercooler water was set at a temperature which reduced the intake air temperature to a level which could be achieved by an air-to-air intercooler operating in an agricultural harvester combine application.

The 1991 model year Ford New Holland heavy-duty diesel engine was an in-line, 6-cylinder, 7.5 L displacement, with no turbocharging or aftercooling. Rated speed and peak torque speeds

for this direct injection engine were 2100 and 1200 RPM respectively, with a rated horsepower of 127 hp.

Table 3.1
Engine Specifications

Manufacturer	John Deere		Ford New Holland
Model	6068H	6068T	
Use	Prototype	Log-Skidder	Agricultural Tractor
Engine Serial Number	JD 6068H 07620	JDPRODT6068T 35JL	358/117-91-89V
Model Year	NA	1990	1991
Rated Power (bhp)	147	139	127
Rated Speed (rpm)	2200	2200	2100
Peak Torque (ft-lb)	442	467	383
Peak Torque Speed (rpm)	1300	1300	1200
Injection Timing (°BTDC)	6	15	8
Cylinder Configuration	in-line	in-line	in-line
Bore x Stroke (in)	4.19 x 5.0	4.19 x 5.0	4.4 x 5.0
Displacement (in^3 - l)	414 - 6.8	414 - 6.8	456 - 7.5
Aspiration	turbo	turbo	natural
Aftercooling	air-air	none	none

4. Fuel

The D-2 diesel fuel used for all testing was purchased from Phillips 66 Company. The characteristics of this fuel were provided by Phillips 66 Company in their product information report, a copy of which is included in the appendix. Pertinent fuel properties are given in Table 4.1.

Table 4.1
Diesel Fuel Analysis and CFR Specifications

Item	CFR Specifications[a]		Phillips Petroleum Analysis
	ASTM	Type D-2	
Cetane Number	D613	42-50	46.0
Distillation Range:			
IBP °F	D86	340-400	364
10% Point, °F	D86	400-460	441
50% Point, °F	D86	470-540	509
90% Point, °F	D86	550-610	580
EP, °F	D86	580-660	622
Gravity, API	D287	33-37	34.8
Total Sulfur, %	D129 or D2622	0.20-0.50	0.26
Hydrocarbon Composition:			
Aromatics, %	D1319	27[b]	36.4
Paraffins, Naphthenes, Olefins	D1319	c	63.6
Flashpoint, °F (min.)	D93	130	180
Viscosity, Centistokes	D445	2.0-3.2	2.6

[a]Diesel fuel specification as in CFR 86.113-90(b)(2) for light-duty diesel vehicles and CFR 86.1313-90(b)(2) for 1990 on-road heavy-duty diesel engines.
[b]Minimum
[c]Remainder

The fuel was introduced to the engine by transferring it from the barrel in which it was shipped to the normal laboratory fuel delivery system by an auxiliary lift pump. It was presented to the engine at a pressure of 0 to 0.5 psi and a temperature less than 100° F.

5. Test Procedures

5.1 Steady State Checkout

Each of the three engines were set up in the EPA NVFEL (National Vehicle and Fuel Emissions Laboratory) test cell #1 and run at measured rated speed and peak torque speed, with the rack lever wide open at both speeds. At both of these conditions, the speed, torque, and fuel flow were measured after stabilization occurred. Each condition was considered stable when the engine oil

temperature stayed within ± 2° F of the stabilized value for two minutes. These speed, torque, and fuel flow values were compared to the manufacturers' data to ensure that the engine was set-up and running correctly.

5.2 Transient Testing

Following a torque map of the engine, two EPA on-highway HD-FTP transient test sequences per engine were performed. A test sequence consisted of one cold-start transient test plus two consecutive hot-start transient tests (sequence = 1 cold-start + 2 hot-start). All gaseous (HC, CO, and NO_x) and particulate matter (PM) emissions were collected for each transient test. The cold-start and first hot-start were used in determining the composite result. The HD-FTP transient emissions tests were performed following procedures given in CFR 40 Part 86 Subpart N for heavy-duty diesel emissions measurement.

5.3 Steady State (8-Mode) Testing

Two 8-mode steady state emission tests were performed on the John Deere 6068T engine and four were performed on the 6068H engine. The extra two tests, the details of which are discussed in section 7.4, on the 6068H engine were used to examine an altered modal order. Three tests were performed on the Ford New Holland engine due to the inconsistencies observed between the first and second test. The particular 8-mode test cycle used is similar to the ISO 8178 8-mode test cycle. Gaseous emissions (HC, CO, and NO_x) and particulate matter (PM) were measured for each individual mode, then a composite brake-specific emission rate was computed using assigned weighting factors. All emissions measurements used dilute full-flow CVS sampling techniques.

A copy of the steady-state particulate measurement procedure is included as appendix A.

6. John Deere 6068T Testing/Results

6.1 Steady State Performance Evaluation

The engine was mounted on the test stand and its flywheel connected to the dynamometer through a drive shaft torquemeter. The exhaust outlet was connected to the part of the system which transfers the exhaust to the dilution tunnel.

With the installation complete, the engine was run at steady state conditions while speeds, torques, and fuel flows were recorded. These values were compared to the engine manufacturer's values (see Table 6.1) and were found to be similar.

Table 6.1
John Deere 6068T Engine
Steady State Performance Data

LAB	TORQUE, FT-LB		FUEL FLOW, GAL/HR	
	1300 RPM	2200 RPM	1300 RPM	2200 RPM
JOHN DEERE VALUES	467.0	332.0	5.7	7.2
EPA VALUES	479.0	334.0	5.7	7.2

6.2 HD-FTP Transient Testing/Results

After the engine was torque mapped, two HD-FTP transient tests were run. Each test consisted of one cold and two hot starts, with the composite results computed from the cold-start and first hot-start. The HD-FTP test results for the non-road John Deere 6068T engine are presented in Table 6.2. The NO_x level of 10.808 g/hp-hr, measured for this engine, is higher than the on-highway pre-control baseline level of 10.7 g/hp-hr. However, the measured PM level of 0.405 g/hp-hr is lower than the on-highway pre-control baseline level of 0.6 g/hp-hr. This is probably due to an advanced engine timing schedule.

Table 6.2
John Deere 6068T Non-Road Engine
Transient Test Results

	HC (g/hp-hr)	CO (g/hp-hr)	NO_x (g/hp-hr)	PM (g/hp-hr)
First Sequence				
Cold Start	1.031	4.189	10.859	0.426
Hot Start #1	0.878	3.803	10.588	0.408
Hot Start #2	0.878	3.598	10.729	0.389
Composite*	0.900	3.858	10.627	0.411
Second Sequence				
Cold Start	1.040	3.723	10.962	0.520
Hot Start #1	0.778	3.291	10.994	0.378
Hot Start #2	0.747	3.400	10.789	0.386
Composite*	0.816	3.353	10.989	0.398
Composite Average	**0.858**	**3.606**	**10.808**	0.405

*Composite = 1/7(Cold Start) + 6/7(Hot Start #1)

6.3 Steady State (8-Mode) Testing/Results

The steady-state test was performed twice on this engine. The ISO 8178 8-mode test cycle, as proposed by CARB, was used along with particulate matter procedures described in appendix A. Composite HC, CO, NO_x, and PM levels were determined to be 0.427, 3.144, 11.758, and 0.422 g/hp-hr respectively. Both NO_x and PM results were higher on the 8-mode steady-state test than on the HD-FTP transient test.

The raw 8-mode steady-state test results are presented in Tables 6.3 and 6.4. These tables are broken down into four groups, with the first grouping of data identifying the actual test modes, and mode weighting factor used in computing the mode-weighted composite brake specific emissions at the bottom of each table. The other groupings of data include a mass emission rate in grams/hour for each mode, a fuel specific emission result at each mode in grams/pound of fuel consumed, and finally the brake specific emission rate at each mode is given in grams/horsepower-hour.

Table 6.3
John Deere 6068T Non-Road Engine
8-Mode Steady-State #1 Emission Results

8-Mode Test Points						
Mode	Speed	Load %	Weighting Factor	Speed rpm	Torque ft-lb	BHP
1	Int	50	10%	1300	244.5	60.5
2	Int	75	10%	1300	360.5	89.2
3	Int	100	10%	1300	482.0	119.3
4	Rated	100	15%	2200	338.0	141.6
5	Rated	75	15%	2200	253.0	106.0
6	Rated	50	15%	2200	169.2	70.9
7	Rated	10	10%	2200	37.0	15.5
8	Idle	0	15%	960	4.0	0.7

Mode g/hr results						
Mode	HP	Fuel lb/hr	HC g/hr	CO g/hr	NO_x g/hr	PM g/hr
1	60.5	20.97	25.27	25.72	847.98	6.39
2	89.2	29.34	27.67	37.16	1311.29	12.02
3	119.3	39.86	21.19	235.79	1641.40	23.29
4	141.6	50.30	35.54	663.68	1667.27	61.21
5	106.0	39.82	28.46	334.40	1027.90	60.74
6	70.9	27.23	42.94	180.05	558.95	46.46
7	15.5	12.56	66.43	112.90	167.47	12.13
8	0.7	2.09	25.98	59.83	68.43	3.86

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO_x g/lb	PM g/lb
1	60.5	NA	1.20	1.23	40.44	0.30
2	89.2	NA	0.94	1.27	44.69	0.41
3	119.3	NA	0.53	5.92	41.18	0.58
4	141.6	NA	0.71	13.19	33.15	1.22
5	106.0	NA	0.71	8.40	25.81	1.53
6	70.9	NA	1.58	6.61	20.53	1.71
7	15.5	NA	5.29	8.99	13.33	0.97
8	0.7	NA	12.43	28.62	32.74	1.84

Mode g/hp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
1	60.5	0.346	0.42	0.42	14.01	0.11
2	89.2	0.329	0.31	0.42	14.70	0.13
3	119.3	0.334	0.18	1.98	13.76	0.20
4	141.6	0.355	0.25	4.69	11.78	0.43
5	106.0	0.376	0.27	3.16	9.70	0.57
6	70.9	0.384	0.61	2.54	7.89	0.66
7	15.5	0.810	4.29	7.28	10.81	0.78
8	0.7	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
	0.346	0.445	2.972	11.728	0.409

Table 6.4
John Deere 6068T Non-Road Engine
8-Mode Steady-State #2 Emission Results

8-Mode Test Points						
Mode	Speed	Load %	Weighting Factor	Speed rpm	Torque ft-lb	BHP
1	Int	50	10%	1300	241.0	59.7
2	Int	75	10%	1300	358.2	88.7
3	Int	100	10%	1300	483.2	119.6
4	Rated	100	15%	2200	335.0	140.3
5	Rated	75	15%	2200	252.1	105.6
6	Rated	50	15%	2200	169.0	70.8
7	Rated	10	10%	2200	36.4	15.2
8	Idle	0	15%	960	4.0	0.7

Mode g/hr results						
Mode	HP	Fuel lb/hr	HC g/hr	CO g/hr	NO_x g/hr	PM g/hr
1	59.7	18.96	22.20	23.16	890.44	6.23
2	88.7	29.42	27.69	40.91	1361.71	12.66
3	119.6	41.95	17.90	301.77	1678.65	25.13
4	140.3	50.37	30.73	678.98	1647.62	63.11
5	105.6	41.93	24.63	398.36	971.83	57.11
6	70.8	27.25	41.08	231.96	548.46	57.82
7	15.2	12.57	60.66	101.58	170.17	12.38
8	0.7	2.09	24.55	57.87	65.21	4.04

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO_x g/lb	PM g/lb
1	59.7	NA	1.17	1.22	46.96	0.33
2	88.7	NA	0.94	1.39	46.29	0.43
3	119.6	NA	0.43	7.19	40.02	0.60
4	140.3	NA	0.61	13.48	32.71	1.25
5	105.6	NA	0.59	9.50	23.18	1.36
6	70.8	NA	1.51	8.51	20.13	2.12
7	15.2	NA	4.83	8.08	13.54	0.98
8	0.7	NA	11.75	27.69	31.20	1.93

Mode g/hp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
1	59.7	0.318	0.37	0.39	14.93	0.10
2	88.7	0.332	0.31	0.46	15.36	0.14
3	119.6	0.351	0.15	2.52	14.04	0.21
4	140.3	0.359	0.22	4.84	11.74	0.45
5	105.6	0.397	0.23	3.77	9.20	0.54
6	70.8	0.385	0.58	3.28	7.75	0.82
7	15.2	0.824	3.98	6.66	11.16	0.81
8	0.7	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
	0.351	0.408	3.316	11.787	0.434

7. John Deere 6068H Testing/Results

7.1 Steady State Performance Evaluation

This engine was installed in the test cell in a manner similar to the 6068T engine and was run at steady state conditions while speeds, torques, and fuel flows were recorded. These values were compared to the engine manufacturer's data (see Table 7.1) in order to determine if the engine was running "correctly." The data was found to be similar. Although there were somewhat large differences in the torque measurements between the manufacturer and EPA, these were judged to be explained by the corresponding fuel flow rates and thus EPA concluded the engine was operating properly.

Table 7.1
John Deere 6068H Engine
Steady State Performance Data

LAB	TORQUE, FT-LB		FUEL FLOW, GAL/HR	
	1300 RPM	2200 RPM	1300 RPM	2200 RPM
JOHN DEERE VALUES	442.0	351.0	5.55	7.63
EPA VALUES	467.0	337.0	5.70	7.45

7.2 HD-FTP Transient Testing/Results

After the engine was torque mapped, two HD-FTP transient tests were run. Composite HC, CO, NO_x and PM levels were determined to be 0.703, 2.573, 6.091, and 0.343 g/hp-hr respectively. Both NO_x and PM were reduced (as well as HC and CO) due to the control technology applied to this engine. The HD-FTP transient test results for the prototype "on-highway" John Deere 6068H engine are presented in Table 7.2.

Table 7.2
John Deere 6068H Prototype "On-Highway" Engine
Transient Test Results

	HC (g/hp-hr)	CO (g/hp-hr)	NO_x (g/hp-hr)	PM (g/hp-hr)
First Sequence				
Cold Start	0.976	3.534	6.193	0.438
Hot Start #1	0.703	2.390	6.096	0.316
Hot Start #2	0.696	2.397	5.924	0.312
Composite*	0.742	2.554	6.110	0.333
Second Sequence				
Cold Start	0.960	3.690	6.332	0.439
Hot Start #1	0.678	2.408	6.028	0.337
Hot Start #2	0.665	2.403	5.893	0.332
Composite*	0.718	2.591	6.071	0.352
Composite Average	**0.730**	**2.573**	**6.091**	**0.343**

*Composite = 1/7(Cold Start) + 6/7(Hot Start #1)

7.3 Steady State (8-Mode) Testing/Results

The steady-state test procedure was run twice on this engine. The ISO 8-mode test cycle, as proposed by CARB, was used along with particulate matter procedures described in appendix A. Composite HC, CO, NO_x, and PM levels were determined to be 0.312, 1.213, 6.066, and 0.180 g/hp-hr respectively. Through the use of this control technology, the HD-FTP transient test showed NO_x and PM reductions of 43.6% and 15.3% respectively, while the steady-state test showed reductions of 48.4% and 57.3% for NO_x and PM.

The raw 8-mode steady-state test results are presented in Tables 7.3 and 7.4.

Table 7.3
John Deere 6068H Prototype "On-Highway" Engine
8-Mode Steady-State #1 Emission Results

8-Mode Test Points						
Mode	Speed	Load %	Weighting Factor	Speed rpm	Torque ft-lb	BHP
1	Int	50	10%	1300	238.0	58.9
2	Int	75	10%	1300	351.0	86.9
3	Int	100	10%	1300	475.0	117.6
4	Rated	100	15%	2200	367.0	153.7
5	Rated	75	15%	2200	283.0	118.5
6	Rated	50	15%	2200	186.0	77.9
7	Rated	10	10%	2200	37.5	15.7
8	Idle	0	15%	822	3.0	0.0

Mode g/hr results						
Mode	HP	Fuel lb/hr	HC g/hr	CO g/hr	NO_x g/hr	PM g/hr
1	58.9	20.27	13.03	26.57	529.79	6.72
2	86.9	29.31	11.24	35.41	729.07	13.28
3	117.6	39.80	6.94	175.56	833.96	29.44
4	153.7	54.64	23.89	42.91	717.55	19.79
5	118.5	41.86	23.64	51.00	580.16	14.52
6	77.9	31.49	27.84	91.85	401.79	14.90
7	15.7	12.56	83.36	334.37	150.56	17.44
8	0.5	2.10	17.83	80.74	72.36	3.62

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO_x g/lb	PM g/lb
1	58.9	NA	0.64	1.31	26.14	0.33
2	86.9	NA	0.38	1.21	24.88	0.45
3	117.6	NA	0.17	4.41	20.95	0.74
4	153.7	NA	0.44	0.79	13.13	0.36
5	118.5	NA	0.56	1.22	13.86	0.35
6	77.9	NA	0.88	2.92	12.76	0.47
7	15.7	NA	6.64	26.62	11.99	1.39
8	0.5	NA	8.49	38.45	34.46	1.72

Mode g/hp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
1	58.9	0.344	0.22	0.45	8.99	0.114
2	86.9	0.337	0.13	0.41	8.39	0.153
3	117.6	0.339	0.06	1.49	7.09	0.250
4	153.7	0.355	0.16	0.28	4.67	0.129
5	118.5	0.353	0.20	0.43	4.89	0.122
6	77.9	0.404	0.36	1.18	5.16	0.191
7	15.7	0.800	5.31	21.29	9.58	1.110
8	0.5	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
	0.365	0.316	1.207	6.088	0.181

Table 7.4
John Deere 6068H Prototype "On-Highway" Engine
8-Mode Steady-State #2 Emission Results

8-Mode Test Points						
Mode	Speed	Load %	Weighting Factor	Speed rpm	Torque ft-lb	BHP
1	Int	50	10%	1300	231.5	57.3
2	Int	75	10%	1300	350.5	86.8
3	Int	100	10%	1300	473.5	117.2
4	Rated	100	15%	2200	369.0	154.6
5	Rated	75	15%	2200	281.5	117.9
6	Rated	50	15%	2200	187.5	78.5
7	Rated	10	10%	2200	39.0	16.3
8	Idle	0	15%	820	12.0	1.9

Mode g/hr results						
Mode	HP	Fuel lb/hr	HC g/hr	CO g/hr	NO_x g/hr	PM g/hr
1	57.3	18.91	12.56	30.68	512.32	6.27
2	86.8	29.34	9.69	33.00	725.80	12.99
3	117.2	39.77	6.73	184.84	833.85	30.12
4	154.6	52.32	22.21	44.41	719.24	17.34
5	117.9	44.13	25.00	52.23	573.64	16.02
6	78.5	31.39	26.30	89.76	410.22	14.83
7	16.3	12.60	81.05	329.63	148.97	17.16
8	1.9	4.19	18.41	83.29	67.61	3.85

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO_x g/lb	PM g/lb
1	57.3	NA	0.66	1.62	27.09	0.33
2	86.8	NA	0.33	1.12	24.74	0.44
3	117.2	NA	0.17	4.65	20.97	0.76
4	154.6	NA	0.42	0.85	13.75	0.33
5	117.9	NA	0.57	1.18	13.00	0.36
6	78.5	NA	0.84	2.86	13.07	0.47
7	16.3	NA	6.43	26.16	11.82	1.36
8	1.9	NA	4.39	19.88	16.14	0.92

Mode g/hp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
1	57.3	0.330	0.22	0.54	8.94	0.11
2	86.8	0.338	0.11	0.38	8.37	0.15
3	117.2	0.339	0.06	1.58	7.11	0.26
4	154.6	0.338	0.14	0.29	4.65	0.11
5	117.9	0.374	0.21	0.44	4.86	0.14
6	78.5	0.400	0.33	1.14	5.22	0.19
7	16.3	0.771	4.96	20.18	9.12	1.05
8	1.9	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
	0.363	0.307	1.218	6.044	0.179

7.4 Alternative Test Cycle

There was interest in the effect of the mode order on emission results in the steady-state test. The alternative mode order (see Table 7.5) especially generated interest because it is easier to perform than the original ISO 8178 steady-state modal order and it decreases the test time by allowing the test to go directly from the warm-up (which is rated conditions) to the first mode (which is also rated conditions) rather than waiting for the engine to stabilize at intermediate speed/50% torque. In addition, by starting the test at rated conditions, some running time was saved by not having to determine the 50 and 75 percent load conditions at peak torque speed needed for the first two modes in the old order.

Table 7.5
Steady-State Mode Orders

	ISO 8178 Steady-State 8-Mode Order							
	1	2	3	4	5	6	7	8
Speed	Int.	Int.	Int.	Rated	Rated	Rated	Rated	Idle
Torque	50%	75%	100%	100%	75%	50%	10%	0%
	Alternative Steady-State 8-Mode Order							
	1	2	3	4	5	6	7	8
Speed	Rated	Rated	Rated	Rated	Int.	Int.	Int.	Idle
Torque	100%	75%	50%	10%	100%	75%	50%	0%

For these reasons the Deere 6068H was run with modes 1-3 reversed and modes 4-7 moved to the beginning. The emission results were compared to previous steady-state testing of this engine and were found to be similar (see Table 7.6). The raw alternative order 8-mode test results are presented in Tables 7.7 and 7.8.

Table 7.6
Results of Reordered Modes for John Deere 6068H

Test Number	Modal Order	BSFC lbs/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
1	ISO 8178	0.365	0.316	1.207	6.088	0.181
2	ISO 8178	0.363	0.307	1.218	6.044	0.179
Average	ISO 8178	0.364	0.312	1.213	6.066	0.180
3	Alt.	0.350	0.349	1.123	5.937	0.174
4	Alt.	0.366	0.405	1.247	5.962	0.167
Average	Alt.	0.358	0.377	1.185	5.950	0.171
% Diff.	----	-1.65	20.83	-2.31	-1.91	-5.00

Table 7.7
John Deere 6068H Prototype "On-Highway" Engine
8-Mode Steady-State #3 Emission Results

8-Mode Test Points						
Mode	Speed	Load %	Weighting Factor	Speed rpm	Torque ft-lb	BHP
1	Rated	100	15%	2200	367.0	153.7
2	Rated	75	15%	2200	278.0	116.5
3	Rated	50	15%	2200	185.0	77.5
4	Rated	10	10%	2200	36.0	15.1
5	Int	100	10%	1300	474.0	117.3
6	Int	75	10%	1300	349.0	86.4
7	Int	50	10%	1300	237.0	58.7
8	Idle	0	15%	820	20.5	3.2

Mode g/hr results						
Mode	HP	Fuel lb/hr	HC g/hr	CO g/hr	NO_x g/hr	PM g/hr
1	153.7	54.59	24.55	43.03	716.62	15.25
2	116.5	41.86	27.76	52.73	556.55	14.30
3	77.5	31.44	29.05	94.21	397.16	14.24
4	15.1	12.61	96.07	354.22	130.46	19.56
5	117.3	37.74	10.40	200.82	811.58	31.82
6	86.4	27.22	9.14	34.31	696.04	11.18
7	58.7	20.94	14.42	27.99	506.98	6.75
8	3.2	2.09	18.83	0.00	80.98	3.29

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO_x g/lb	PM g/lb
1	153.7	NA	0.45	0.79	13.13	0.28
2	116.5	NA	0.66	1.26	13.30	0.34
3	77.5	NA	0.92	3.00	12.63	0.45
4	15.1	NA	7.62	28.09	10.35	1.55
5	117.3	NA	0.28	5.32	21.50	0.84
6	86.4	NA	0.34	1.26	25.57	0.41
7	58.7	NA	0.69	1.34	24.21	0.32
8	3.2	NA	9.01	0.00	38.74	1.57

Mode g/hp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
1	153.7	0.355	0.16	0.28	4.66	0.10
2	116.5	0.359	0.24	0.45	4.78	0.12
3	77.5	0.406	0.37	1.22	5.13	0.18
4	15.1	0.836	6.37	23.49	8.65	1.30
5	117.3	0.322	0.09	1.71	6.92	0.27
6	86.4	0.315	0.11	0.40	8.06	0.13
7	58.7	0.357	0.25	0.48	8.64	0.12
8	3.2	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
	0.350	0.349	1.123	5.937	0.174

Table 7.8
John Deere 6068H Prototype "On-Highway" Engine
8-Mode Steady-State #4 Emission Results

8-Mode Test Points						
Mode	Speed	Load %	Weighting Factor	Speed rpm	Torque ft-lb	BHP
1	Rated	100	15%	2200	368.0	154.2
2	Rated	75	15%	2200	280.0	117.3
3	Rated	50	15%	2200	185.0	77.5
4	Rated	10	10%	2200	35.5	14.9
5	Int	100	10%	1300	471.5	116.7
6	Int	75	10%	1300	351.0	86.9
7	Int	50	10%	1300	233.0	57.7
8	Idle	0	15%	820	20.0	3.1

Mode g/hr results						
Mode	HP	Fuel lb/hr	HC g/hr	CO g/hr	NO_x g/hr	PM g/hr
1	154.2	54.57	31.94	45.49	684.87	15.94
2	117.3	41.92	34.27	54.00	556.78	14.88
3	77.5	31.49	35.80	92.15	404.44	14.58
4	14.9	10.50	105.92	349.08	140.86	16.92
5	116.7	39.84	8.90	170.32	834.80	27.16
6	86.9	27.22	10.64	31.54	714.95	10.96
7	57.7	20.93	15.54	30.92	507.40	6.47
8	3.1	2.09	21.15	89.12	84.86	3.37

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO_x g/lb	PM g/lb
1	154.2	NA	0.59	0.83	12.55	0.29
2	117.3	NA	0.82	1.29	13.28	0.35
3	77.5	NA	1.14	2.93	12.84	0.46
4	14.9	NA	10.09	33.25	13.42	1.61
5	116.7	NA	0.22	4.28	20.95	0.68
6	86.9	NA	0.39	1.16	26.27	0.40
7	57.7	NA	0.74	1.48	24.24	0.31
8	3.1	NA	10.12	42.64	40.60	1.61

Mode g/hp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
1	154.2	0.354	0.21	0.30	4.44	0.10
2	117.3	0.357	0.29	0.46	4.75	0.13
3	77.5	0.406	0.46	1.19	5.22	0.19
4	14.9	0.706	7.12	23.47	9.47	1.14
5	116.7	0.341	0.08	1.46	7.15	0.23
6	86.9	0.313	0.12	0.36	8.23	0.13
7	57.7	0.363	0.27	0.54	8.80	0.11
8	3.1	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
	0.366	0.405	1.247	5.962	0.167

The percent changes in BSFC, CO, NO_x, and PM due to the different modal order were small; however, a +20.8% change in HC resulted from the new alternative order. By looking at each mode separately (see Figure 7.1) it was evident that the emission of HC increased even in the modes where the preconditioning mode remained the same (Rated/75%, Rated/50%, and Rated/10%). This is evidence that the HC increase can probably be attributed to an engine-out variability rather than a test procedure (modal order) variability. This conclusion is further supported by looking at the test to test HC variability, which is rather large in comparison to the other pollutants.

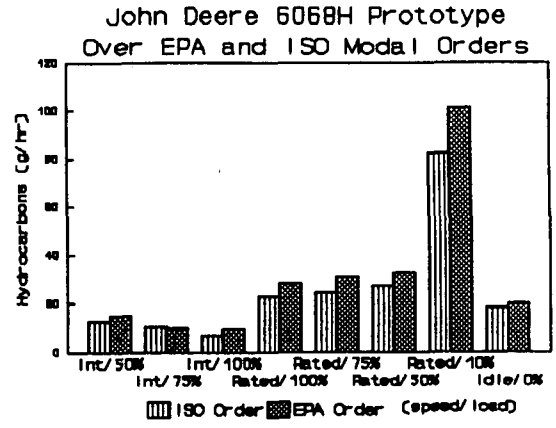


Figure 7.1

In addition, John Deere tested a turbocharged four-cylinder, 4.5 liter displacement, heavy-duty diesel engine with both modal orders and did not see a large difference in HC or any of the other gaseous emissions (see appendix D and Table 7.9). This generator set engine was rated at 110 hp at 1800 rpm and was tested using 0.3% sulfur fuel. Based on these data, it was determined that the Ford New Holland engine could be tested accurately with the different modal order.

Table 7.9
Changes in Emissions Due to Modal Order

	HC	CO	NO_x	PM
EPA (6068H)	20.8%	-2.3%	-1.9%	-5.0%
John Deere (4045T)	-0.5%	-1.5%	-0.5%	--

8. Ford New Holland Testing/Results

8.1 Steady State Performance Evaluation

The Ford New Holland engine was installed in the test cell and the torque and fuel flow data values were recorded as with the John Deere engines. As with previous engines, these values were compared to the engine manufacturer's predictions (see Table 8.1) in order to determine if the engine was running "correctly." The data were found to be similar.

Table 8.1
Ford New Holland Engine
Steady State Performance Data

LAB	TORQUE, FT-LB		FUEL FLOW, GAL/HR	
	1200 RPM	2100 RPM	1200 RPM	2100 RPM
FORD N.H. VALUES	383.0	318.0	4.5	7.0
EPA VALUES	380.5	324.0	4.5	7.2

8.2 HD-FTP Transient Testing/Results

Composite transient test HC, CO, NO_x and PM levels were determined to be 2.571, 6.267, 9.656, and 1.031 g/hp-hr respectively. The NO_x level was near uncontrolled on-road levels, and the PM was relatively high, especially considering the NO_x level. Raw transient test results for the Ford New Holland engine are presented in Table 8.2.

Table 8.2
Ford New Holland Engine
Transient Test Results

	HC (g/hp-hr)	CO (g/hp-hr)	NO_x (g/hp-hr)	PM (g/hp-hr)
First Sequence				
Cold Start	3.326	6.991	10.162	1.237
Hot Start #1	2.593	5.948	9.622	1.050
Hot Start #2	2.328	5.936	10.013	1.015
Composite*	2.696	6.094	9.698	1.076
Second Sequence				
Cold Start	2.925	7.640	10.606	1.074
Hot Start #1	2.366	6.239	9.447	0.970
Hot Start #2	2.245	6.180	9.333	0.991
Composite*	2.446	6.439	9.613	0.985
Composite Average	**2.571**	**6.267**	**9.656**	**1.031**

*Composite = 1/7(Cold Start) + 6/7(Hot Start #1)

8.3 Steady State (8-Mode) Testing/Results

For testing this engine, the modes were reordered as discussed in section 7.4. Three steady-state tests were run on this engine. The third steady-state was run because there was an inconsistency in the results of the first two. Composite steady-state HC, CO, NO_x, and PM levels were determined to be 0.947, 6.395, 7.601, and 1.020 g/hp-hr respectively. The values for CO and PM were similar for both test procedures, but HC and NO_x were 21% and 45% lower on the 8-mode steady-state test than on the HD-FTP, respectively.

The raw 8-mode steady-state test results are presented in Tables 8.3 through 8.5.

Table 8.3
Ford New Holland Engine
8-Mode Steady-State #1 Emission Results

8-Mode Test Points						
Mode	Speed	Load %	Weighting Factor	Speed rpm	Torque ft-lb	BHP
1	Rated	100	15%	2100	330.0	131.8
2	Rated	75	15%	2100	252.2	100.9
3	Rated	50	15%	2100	160.4	64.1
4	Rated	10	10%	2100	35.0	14.0
5	Int.	100	10%	1260	384.1	92.1
6	Int.	75	10%	1258	286.2	68.6
7	Int.	50	10%	1260	196.5	47.1
8	Idle	0	15%	750	1.0	0.1

Mode g/hr results						
Mode	HP	Fuel lb/hr	HC g/hr	CO g/hr	NO_x g/hr	PM g/hr
1	131.8	50.81	14.28	1255.29	872.45	221.26
2	100.9	40.22	60.32	369.84	625.08	59.78
3	64.1	25.37	94.30	192.39	356.42	26.89
4	14.0	12.68	245.42	282.84	54.68	62.78
5	92.1	33.82	30.47	1871.44	1026.32	166.28
6	68.6	23.24	42.72	136.36	650.60	16.76
7	47.1	15.85	51.86	53.21	434.52	19.68
8	0.1	2.11	37.48	43.01	27.14	4.70

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO_x g/lb	PM g/lb
1	131.8	NA	0.28	24.71	17.17	4.35
2	100.9	NA	1.50	9.20	15.54	1.49
3	64.1	NA	3.72	7.58	14.05	1.06
4	14.0	NA	19.35	22.31	4.31	4.95
5	92.1	NA	0.90	55.34	30.35	4.92
6	68.6	NA	1.84	5.87	27.99	0.72
7	47.1	NA	3.27	3.36	27.41	1.24
8	0.1	NA	17.76	20.38	12.86	2.23

Mode g/hp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
1	131.8	0.385	0.11	9.52	6.62	1.68
2	100.9	0.398	0.60	3.66	6.19	0.59
3	64.1	0.396	1.47	3.00	5.56	0.42
4	14.0	0.906	17.54	20.21	3.91	4.49
5	92.1	0.367	0.33	20.31	11.14	1.80
6	68.6	0.339	0.62	1.99	9.49	0.24
7	47.1	0.336	1.10	1.13	9.22	0.42
8	0.1	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
	0.362	1.019	7.694	7.473	1.100

Table 8.4
Ford New Holland Engine
8-Mode Steady-State #2 Emission Results

8-Mode Test Points						
Mode	Speed	Load %	Weighting Factor	Speed rpm	Torque ft-lb	BHP
1	Rated	100	15%	2100	328.0	131.2
2	Rated	75	15%	2100	247.0	98.8
3	Rated	50	15%	2100	168.0	67.2
4	Rated	10	10%	2100	31.0	12.4
5	Int	100	10%	1260	384.0	92.1
6	Int	75	10%	1260	284.5	68.3
7	Int	50	10%	1260	189.0	45.3
8	Idle	0	15%	745	1.0	0.1

Mode g/hr results						
Mode	HP	Fuel lb/hr	HC g/hr	CO g/hr	NO_x g/hr	PM g/hr
1	131.2	49.53	12.74	1069.07	939.08	211.73
2	98.8	34.85	61.56	308.52	678.77	60.83
3	67.2	25.79	83.99	156.43	467.71	36.13
4	12.4	11.15	180.94	256.03	90.77	42.24
5	92.1	33.44	21.76	1052.03	698.69	104.10
6	68.3	22.28	49.38	91.48	665.46	18.32
7	45.3	13.93	50.16	49.64	408.42	23.02
8	0.1	1.39	36.71	39.74	30.60	5.43

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO_x g/lb	PM g/lb
1	131.2	NA	0.26	21.58	18.96	4.27
2	98.8	NA	1.77	8.85	19.48	1.75
3	67.2	NA	3.26	6.07	18.14	1.40
4	12.4	NA	16.23	22.96	8.14	3.79
5	92.1	NA	0.65	31.46	20.89	3.11
6	68.3	NA	2.22	4.11	29.87	0.82
7	45.3	NA	3.60	3.56	29.32	1.65
8	0.1	NA	26.41	28.59	22.02	3.91

Mode g/hp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
1	131.2	0.378	0.10	8.15	7.16	1.61
2	98.8	0.353	0.62	3.12	6.87	0.62
3	67.2	0.384	1.25	2.33	6.96	0.54
4	12.4	0.900	14.60	20.66	7.32	3.41
5	92.1	0.363	0.24	11.42	7.58	1.13
6	68.3	0.326	0.72	1.34	9.75	0.27
7	45.3	0.307	1.11	1.09	9.01	0.51
8	0.1	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
	0.354	0.896	5.738	7.587	0.992

Table 8.5
Ford New Holland Engine
8-Mode Steady-State #3 Emission Results

8-Mode Test Points						
Mode	Speed	Load %	Weighting Factor	Speed rpm	Torque ft-lb	BHP
1	Rated	100	15%	2100	328.0	131.2
2	Rated	75	15%	2100	228.0	91.2
3	Rated	50	15%	2100	162.0	64.8
4	Rated	10	10%	2100	34.4	13.8
5	Int.	100	10%	1260	383.0	91.9
6	Int.	75	10%	1260	286.0	68.6
7	Int.	50	10%	1260	196.0	47.0
8	Idle	0	15%	750	6.0	0.9

Mode g/hr results						
Mode	HP	Fuel lb/hr	HC g/hr	CO g/hr	NO_x g/hr	PM g/hr
1	131.2	64.88	11.05	993.68	991.63	206.76
2	91.2	32.79	58.37	230.96	639.98	47.06
3	64.8	25.07	89.51	155.93	448.83	27.99
4	13.8	11.84	179.96	273.26	98.46	45.02
5	91.9	32.73	23.90	1129.76	682.94	107.82
6	68.6	27.16	46.84	129.57	724.53	22.33
7	47.0	14.62	50.21	58.42	403.46	23.46
8	0.9	1.39	43.68	64.10	19.03	7.47

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO_x g/lb	PM g/lb
1	131.2	NA	0.17	15.32	15.28	3.19
2	91.2	NA	1.78	7.04	19.52	1.44
3	64.8	NA	3.57	6.22	17.90	1.12
4	13.8	NA	15.20	23.08	8.32	3.80
5	91.9	NA	0.73	34.52	20.87	3.29
6	68.6	NA	1.72	4.77	26.68	0.82
7	47.0	NA	3.43	4.00	27.60	1.60
8	0.9	NA	31.42	46.11	13.69	5.38

Mode g/hp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
1	131.2	0.495	0.08	7.58	7.56	1.58
2	91.2	0.360	0.64	2.53	7.02	0.52
3	64.8	0.387	1.38	2.41	6.93	0.43
4	13.8	0.861	13.08	19.87	7.16	3.27
5	91.9	0.356	0.26	12.30	7.43	1.17
6	68.6	0.396	0.68	1.89	10.56	0.33
7	47.0	0.311	1.07	1.24	8.58	0.50
8	0.9	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/hp-hr	CO g/hp-hr	NO_x g/hp-hr	PM g/hp-hr
	0.357	0.926	5.753	7.744	0.968

9. Analysis and Conclusions

Emission data were taken from a John Deere 6068T production, 1990 model year, heavy-duty diesel engine. NO_x and PM values for the 8-mode test were both within 9.0% of the HD-FTP values for this engine. The NO_x and PM values were lower on the HD-FTP test than on the 8-mode test. There was also some agreement for CO (8-mode test result was 15.3% smaller than the HD-FTP result); however, the 8-mode HC value was only half of the HD-FTP value.

Emission data were also taken from a John Deere 6068H prototype "on-highway" engine. Only the NO_x values correlated well between the HD-FTP and 8-mode tests for this engine (0.4% difference). HC, CO, NO_x and PM values were all higher on the HD-FTP test than on the 8-mode test.

The prototype "on-highway" John Deere 6068H engine had significantly lower NO_x emissions than the production John Deere 6068T engine. Relative reductions shown by the HD-FTP test results agreed well with the 8-mode test results for NO_x. However, the 8-mode test showed much higher reductions in HC, CO and PM than did the transient test. All of the data mentioned above are shown in the following table:

Table 9.1
Emissions Summary For John Deere 6068 Engines

John Deere 6068T Production Engine

	HC (g/hp-hr)	CO (g/hp-hr)	NO_x (g/hp-hr)	PM (g/hp-hr)
HD-FTP, Transient	0.858	3.606	10.808	0.405
8-Mode, Steady-State	0.427	3.054	11.758	0.422

John Deere 6068H Prototype Engine

	HC (g/hp-hr)	CO (g/hp-hr)	NO_x (g/hp-hr)	PM (g/hp-hr)
HD-FTP, Transient	0.730	2.573	6.091	0.343
8-Mode, Steady-State	0.312	1.213	6.066	0.180

Reductions in the John Deere Engine Due to On-Highway Control

	HC (g/hp-hr)	CO (g/hp-hr)	NO_x (g/hp-hr)	PM (g/hp-hr)
HD-FTP, Transient	14.9%	28.2%	43.6%	15.3%
8-Mode, Steady-State	26.9%	60.3%	48.4%	57.3%

Finally, a Ford New Holland production, 1990 model year, heavy-duty diesel engine was emission tested. CO and PM values for the 8-mode steady-state test were both within 2% of the corresponding transient test values. The 8-mode HC and NO_x values were 21% lower and 45% lower, respectively, relative to the HD-FTP.

The results for this engine are summarized in the following table:

Table 9.2
Emissions Summary For Ford New Holland Engine

Ford New Holland Production Engine

	HC (g/hp-hr)	CO (g/hp-hr)	NO_x (g/hp-hr)	PM (g/hp-hr)
HD-FTP, Transient	2.571	6.267	9.656	1.031
8-Mode, Steady-State	0.947	6.395	7.601	1.020

For all three engines/configurations, the HD-FTP test results were generally higher than the 8-mode steady-state test results. The only three exceptions to this were the NO_x and PM values for the production John Deere 6068T engine and the CO value for the Ford New Holland engine.

Based on this testing program, two general conclusions can be drawn. The first regards NO_x. From the John Deere data, the 8-mode test resulted in similar NO_x values as compared to the HD-FTP test data, even after the application of moderate control technology. However, some caution is warranted since this correspondence was not as evident in the Ford New Holland data. Second, there was little agreement between the 8-mode test and the HD-FTP transient test for HC, CO, or PM.

Appendices

A. Particulate Measurement Procedure

Steady State Particulate Measurement Example Using Full Exhaust Dilution

Introduction

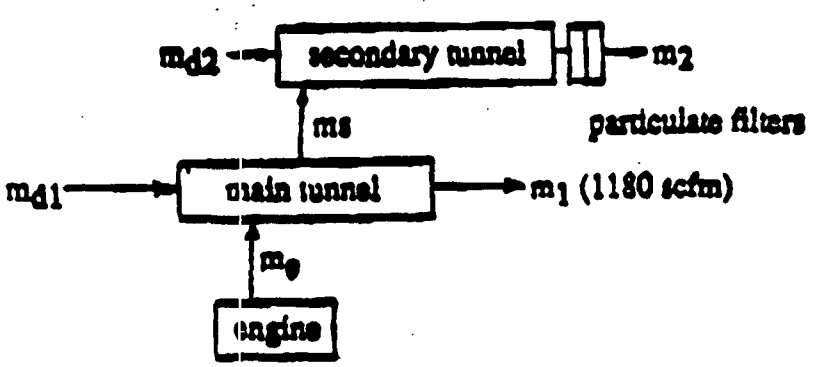
The primary objective of obtaining a particulate filter sample is to determine the engine exhaust particulate signature. Since this particulate signature can be as much a function of the measurement procedure as the engine design, specific guidelines are necessary to ensure that all laboratories perform similar measurements. Guidelines for flow measurement accuracies, particulate sampling options, filter parameters (sizes, compositions, weighing and conditioning procedures), calibration of particulate system, and test sequences are not detailed here since these are in 40 CFR Part 86-Subpart N, SAE J2182, and ISO 8178.

In addition to the above guidelines, the following example is offered to illustrate an overview of how a typical steady state particulate measurement is performed. The test engine for this sample procedure is a 160 hp turbocharged and aftercooled diesel engine exhausting into a full dilution tunnel such as used for transient testing. If a smaller or larger engine were to be tested, the primary, secondary, or both tunnel flows would need to be adjusted accordingly, e.g., primary tunnel flow lower by about half for an 80hp engine, or higher by about two for a 300 hp engine. These tunnel flows are estimates only, not the results of energy balances because exact calculations require knowledge of the heat loss characteristics of sampling systems.

Schematic

The following sketch illustrates the major system parts and flows: engine exhaust (m_e), main tunnel dilution air (m_d), diluted exhaust sample from main tunnel (m_s), flow from main tunnel (m_1), and flow from secondary tunnel (m_2). Dilution air flow to the secondary tunnel is not reported because that will differ from system to system, depending on heat losses, and it must be adjusted to obtain a filter temperature of 52 °C or lower. A critical flow venturi (CFV) with a nominal 1180 scfm flow rate was used for the main tunnel in this example. Flow is constant with a CFV except for slight differences from mode to mode due to temperature variations. Two particulate filters are required; the first filter collects most of the exhaust particulate and must be at or below 52 °C, while the secondary filter is usually slightly cooler . The secondary filter particulate mass must be added to the main filter particulate to determine the total particulate mass.

The filter temperature is adjusted by changing the secondary tunnel dilution flow rate. Systems with main tunnel positive displacement pumps (PDP) can offer the option of filter temperature control with either main or secondary tunnel flow adjustments. Transient or steady state particulate tests can be obtained with either type of system, or with systems that offer only main tunnel flow adjustment. The most important criterion is to obtain a filter temperature of 52 °C or lower. Other test parameters, such as main tunnel dilution ratio, sample flow rates, secondary tunnel flow, etc. can differ from system to system without violating the test validity, but prudence suggests that labs planning to compare data should keep constant as many system parameters as possible.



Engine Warm Up

Before beginning the 8-mode test, warm up the engine at full load rated speed until exhaust temperature is stable to within 5 °C for a one minute time period. Stabilize the engine at each mode to achieve the 5 °C exhaust temperature for one minute except idle, which should stabilize for 5 minutes without regard for temperature. Record the engine operating time spent during stabilization and data collection.

Between test modes the particulate filters and gaseous emission bags must be changed. Labs that are able to perform these tasks with the engine running should proceed to the next test point for engine stabilization. Labs that cannot permit the engine to run during bag and filter changes should follow the procedure required to change filters without the engine running, minimize the downtime, restart the engine, arrive at the 5 °C exhaust temperature stability point as soon as possible and document the duration of engine downtime, plus the warm up and data recording times. For the idle mode, if the engine has been off for more than 20 minutes, then warm up the engine and tunnel for 5 minutes at prior mode conditions (the prior in this example is 10% load, rated speed), then proceed to idle mode and stabilize for 5 minutes.

Practice Filter(s)

In order to set dilution flows, follow the engine warm-up period with a practice filter collection as if actual testing were being performed. The sample time for this practice filter should be 10 minutes or less, as is expected for actual testing. The sample duration and dilution flows selected will depend on the experience of performing such a test on a given engine. If sample time or dilution ratio must be adjusted to comply with the minimum filter mass or maximum filter temperature criteria, then another practice run must be made, as illustrated in the table below, designated as the two "set" modes. The primary tunnel flows should be set to get the system into the "ballpark", with the secondary tunnel flows used to "fine tune" the measurement so that particulate filter sample temperature is less than 52 °C. Some trial and error may be necessary to achieve a filter temperature of 52 °C or lower. Once the tunnel flows are set during the practice run, these values should remain fixed for the duration of testing, unless filter temperature exceeds 52 °C, which requires flow adjustment to include more dilution air. Since the practice filter was obtained at a high exhaust temperature condition, the flows set during the practice run should be adequate to ensure filter temperatures of 52 °C or lower at all other conditions. Some dilution systems may experience heat accumulation as subsequent tests are performed; secondary dilution flow increase can compensate for heat accumulation and achieve 52 °C filter temperature.

Obtaining Filter Data

After the engine warm-up and practice filter exercises are completed, proceed to the first test point (50% load, intermediate speed) and stabilize the engine as per the 5 °C exhaust temperature in one minute as specified above. The following table illustrates actual data obtained as described above. The rated point (mode 4) was at a 3:1 dilution ratio for this example. Similar tests at other labs may not be able to achieve 3:1 dilution ratio at rated. A general target range is 2:1 to 6:1 at rated, with proportional values for modes 1-3 and 5-8.

The filter temperatures at modes 1, 7 and 8 are lower than the 42 °C minimum limit specified in ISO 8178, but lower dilution is not possible since the primary tunnel flow is constant at 1180 scfm, and changing the primary flow would require a venturi change. Mode 8 (idle) will present difficulty since the idle point exhaust temperature is low, as is the particulate rate, which will require long sample times for collecting adequate filter mass. Although low dilution is desired at this point to keep temperature high and sample times low, the transient certification test is run with high dilution at idle points, so a more accurate simulation of the transient test is expected if the primary tunnel flow rate is not changed at idle. If sample times needed to collect adequate filter mass exceed 20 minutes (the transient test sample time), the 20 minute sample can be accepted. If test needs beyond the scope of the current investigation require special attention to a low particulate operating point, then see the "Options" section below for guidance.

Sample Data Sheet

90 mm diameter filter, 1150 scfm primary tunnel flow, 10 minute sample time per mode. Values of m_{ed}, m_{ep}, % sample, main dilution ratio and sample time are nominal; deviation from these values is acceptable. This table is only an example; judgment should be used when deviating from these values if lab to lab comparisons are anticipated.

Mode	RPM	Load	mass (mg)	temp (°C)	m_e (scfm)	m_s (scfm)	% sample*	Main ** D. Ratio	Sample Time (min)
set	rtd.	100	4.4	59	370	1.65	.14	3	10
set	rtd.	100	4.2	52	370	1.65	.14	3	10
1	int.	50	2.4	35	164	1.65	.14	7	10
2	int.	75	2.8	42	178	1.65	.14	7	10
3	int.	100	4.6	47	202	1.65	.14	6	10
4	rtd.	100	4.2	52	370	1.65	.14	3	10
5	rtd.	75	3.1	50	336	1.65	.14	4	10
6	rtd.	50	3.2	46	307	1.65	.14	4	10
7	rtd.	10	2.1	38	250	1.65^	.14 ^	5	10
8	idle	0	1.9	23	92	1.65^	.14 ^	13	10

* Sample flow rate as a percent of main tunnel flow, $100\% * m_s/1150$
The % sample and m_{ed} data are design target suggestions that varied from test to test by ± 0.02% (0.2 scfm). These flows need not be the same for all test labs, but similar flow rates among labs are encouraged for better lab to lab comparisons. A competing factor that prompts deviation from constant m_s is the desire to increase sample mass at idle and low loads or any light particulate load point, such as those identified by "^".

** Main tunnel dilution ratio, $1150/m_e$

Options

These flow conditions need not be duplicated in exact detail at each test laboratory. The flow conditions needed to obtain filter temperatures of 52 °C or lower are difficult to predict due to heat losses that will differ from system to system. Note that most of the modes resulted in filter temperatures that were well below 52 °C. A PDP system with a variable blower drive could achieve 52 °C for all modes by decreasing the primary tunnel flow, but for laboratories that expect to compare data, the primary tunnel flows should be as similar as possible. In addition, since comparisons of 8-mode and transient data are to be made at similar test conditions, the steady-state tests should be performed as closely as possible to transient conditions, which are run at constant primary tunnel total flow rates. Variable blower drive PDP labs should use the CFV primary tunnel flow rates of labs that will be part of comparison testing. Similarly, labs that use split and dilute sampling methods should target for the same general primary dilution ratios as full dilution tunnel labs that will be part of data comparisons.

If inadequate filter mass is collected and the test point is of special interest, then dilution ratios should be decreased to ensure that adequate filter mass is collected. An option is to not use double dilution to increase the filter mass, provided the filter temperature is 52 °C or lower.
An example is the idle point, which probably will not result in sufficient mass according to ISO guidelines. The decision to respecify the dilution air quantity requires judgment and an understanding of the test objective. For example, the filter mass criteria specified in ISO 8178 or SAE J2182, can be waived for idle due to its low contribution to overall 8-mode particulate mass if the test objective is to determine the cumulative 8-mode particulate value. If the test objective is idle mode engine development, then a dilution ratio that permits maximum idle mode mass determination accuracy is suggested.

B. Raw Transient Test Emission Data

DIESEL SUMMARY REPORT

JOHN DEERE 6068T PRODUCTION ENGINE TRANSIENT TEST #1
COLD START

Test Number: HD-910247 Manufacturer: EXPERIMENTAL
Test Date/Time: 8-22-91 7:53 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA

Barometer: 29.02 "HG
Dry Bulb Temperature: 84.10 F
Absolute Humidity: 57.99 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	3.93	.00	
Exhaust+Bkg, Gm	13.20	.00	
Net, Gm/Bhp-Hr	.000	.000	1.031
CO (BAG)			
Background, PPM	2.20	.00	
Exhaust+Bkg, Gm	46.72	.00	
Net, Gm/Bhp-Hr	.00	.00	4.19
NOX (INTEGRATED)			
Background, PPM	1.00	.00	
Exhaust+Bkg, Gm	121.22	.00	
Net, Gm/Bhp-Hr	.000	.000	10.859
CO2 (BAG)			
Background, PPM	.039	.000	
Exhaust+Bkg, Gm	6392.17	.00	
Net, Gm/Bhp-Hr	.0	.0	537.1
PARTICULATE			
Secondary Tare, GM	.156138	.000000	
Secondary Part, GM	.156243	.000000	
Primary Tare, GM	.156405	.000000	
Primary Part, GM	.160155	.000000	
Total, Gm/Bhp-Hr	.43	.00	.43
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	3.906
Lbs/Bhp-Hr	.000	.000	.371
Lbs/Measured	4.465	.000	
BRAKE HORSEPOWER-HOUR	10.515	.000	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	0
Slope	.99498	.00000
(Limit: 0.97-1.03)		
Y-Intercept	14.056	.000
(Limit: +-50 RPM)		
Std Error	17.916	.000
(Limit: 100 RPM)		
R-Square	.99875	.00000
(Limit: 0.97)		
TORQUE		
Number	997	0
Slope	.99563	.00000
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-5.552	.000
(Limit: +-15 Ft-Lbs)		
Std Error	5.121%	.000%
(Limit: 13% Max Eng Tq)		
R-Square	.96570	.00000
(Limit: 0.85/0.88)		
POWER		
Number	997	0
Slope	.99334	.00000
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-1.711	.000
(Limit: +-5 BHP)		
Std Error	5.748%	.000%
(Limit: 8%)		
R-Square	.96827	.00000
(Limit: 0.91)		
WORK		
Actual	10.515	.000
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	10.733	.000
% Difference	-2.03%	.00%

DIESEL SUMMARY REPORT

JOHN DEERE 6068T PRODUCTION ENGINE TRANSIENT TEST #1
HOT START #1

Test Number: HD-910248 Manufacturer: EXPERIMENTAL
Test Date/Time: 8-22-91 8:38 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA

Barometer: 29.02 "HG
Dry Bulb Temperature: 83.40 F
Absolute Humidity: 60.21 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	4.00	
Exhaust+Bkg, Gm	.00	11.58	
Net, Gm/Bhp-Hr	.000	.000	.878
CO (BAG)			
Background, PPM	.00	2.20	
Exhaust+Bkg, Gm	.00	42.41	
Net, Gm/Bhp-Hr	.00	.00	3.80
NOX (INTEGRATED)			
Background, PPM	.00	1.00	
Exhaust+Bkg, Gm	.00	116.87	
Net, Gm/Bhp-Hr	.000	.000	10.588
CO2 (BAG)			
Background, PPM	.000	.037	
Exhaust+Bkg, Gm	.00	6146.17	
Net, Gm/Bhp-Hr	.0	.0	519.9
PARTICULATE			
Secondary Tare, GM	.000000	.155887	
Secondary Part, GM	.000000	.156050	
Primary Tare, GM	.000000	.151980	
Primary Part, GM	.000000	.155598	
Total, Gm/Bhp-Hr	.00	.41	.41
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	3.752
Lbs/Bhp-Hr	.000	.000	.359
Lbs/Measured	.000	4.111	
BRAKE HORSEPOWER-HOUR	.000	10.449	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99443	.99443
(Limit: 0.97-1.03)		
Y-Intercept	13.597	13.597
(Limit: +-50 RPM)		
Std Error	17.776	17.776
(Limit: 100 RPM)		
R-Square	.99877	.99877
(Limit: 0.97)		
TORQUE		
Number	997	997
Slope	.99654	.99654
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-6.654	-6.654
(Limit: +-15 Ft-Lbs)		
Std Error	5.503%	5.503%
(Limit: 13% Max Eng Tq)		
R-Square	.96067	.96067
(Limit: 0.85/0.88)		
POWER		
Number	997	997
Slope	.99406	.99406
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-2.136	-2.136
(Limit: +-5 BHP)		
Std Error	6.229%	6.229%
(Limit: 8%)		
R-Square	.96300	.96300
(Limit: 0.91)		
WORK		
Actual	.000	10.449
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	10.733
% Difference	.00%	-2.65%

DIESEL SUMMARY REPORT

Test Number: HD-910249 Manufacturer: EXPERIMENTAL
Test Date/Time: 8-22-91 9:17 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA

Barometer: 29.02 "HG
Dry Bulb Temperature: 83.00 F
Absolute Humidity: 62.03 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	4.23	
Exhaust+Bkg, Gm	.00	11.69	
Net, Gm/Bhp-Hr	.000	.000	.878
CO (BAG)			
Background, PPM	.00	1.98	
Exhaust+Bkg, Gm	.00	39.92	
Net, Gm/Bhp-Hr	.00	.00	3.60
NOX (INTEGRATED)			
Background, PPM	.00	1.00	
Exhaust+Bkg, Gm	.00	117.62	
Net, Gm/Bhp-Hr	.000	.000	10.729
CO2 (BAG)			
Background, PPM	.000	.033	
Exhaust+Bkg, Gm	.00	6035.50	
Net, Gm/Bhp-Hr	.0	.0	516.9
PARTICULATE			
Secondary Tare, GM	.000000	.156347	
Secondary Part, GM	.000000	.156536	
Primary Tare, GM	.000000	.154878	
Primary Part, GM	.000000	.158141	
Total, Gm/Bhp-Hr	.00	.39	.39
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	3.720
Lbs/Bhp-Hr	.000	.000	.357
Lbs/Measured	.000	4.111	
BRAKE HORSEPOWER-HOUR	.000	10.426	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99410	.99410
(Limit: 0.97-1.03)		
Y-Intercept	13.609	13.609
(Limit: +-50 RPM)		
Std Error	17.349	17.349
(Limit: 100 RPM)		
R-Square	.99882	.99882
(Limit: 0.97)		
TORQUE		
Number	997	997
Slope	.99615	.99615
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-6.820	-6.820
(Limit: +-15 Ft-Lbs)		
Std Error	5.593%	5.593%
(Limit: 13% Max Eng Tq)		
R-Square	.95939	.95939
(Limit: 0.85/0.88)		
POWER		
Number	997	997
Slope	.99344	.99344
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-2.199	-2.199
(Limit: +-5 BHP)		
Std Error	6.350%	6.350%
(Limit: 8%)		
R-Square	.96154	.96154
(Limit: 0.91)		
WORK		
Actual	.000	10.426
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	10.733
% Difference	.00%	-2.86%

JOHN DEERE 6068T PRODUCTION ENGINE TRANSIENT TEST #1
HOT START #2

DIESEL SUMMARY REPORT

JOHN DEERE 6068T PRODUCTION ENGINE TRANSIENT TEST #2
COLD START

Test Number: HD-910259 Manufacturer: EXPERIMENTAL
Test Date/Time: 8-28-91 8: 5 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA

Barometer: 29.25 "HG
Dry Bulb Temperature: 84.70 F
Absolute Humidity: 60.63 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	4.00	.00	
Exhaust+Bkg, Gm	13.38	.00	
Net, Gm/Bhp-Hr	.000	.000	1.040
CO (BAG)			
Background, PPM	3.31	.00	
Exhaust+Bkg, Gm	43.28	.00	
Net, Gm/Bhp-Hr	.00	.00	3.72
NOX (INTEGRATED)			
Background, PPM	1.00	.00	
Exhaust+Bkg, Gm	121.87	.00	
Net, Gm/Bhp-Hr	.000	.000	10.962
CO2 (BAG)			
Background, PPM	.041	.000	
Exhaust+Bkg, Gm	6504.66	.00	
Net, Gm/Bhp-Hr	.0	.0	542.9
PARTICULATE			
Secondary Tare, GM	.158910	.000000	
Secondary Part, GM	.159113	.000000	
Primary Tare, GM	.158008	.000000	
Primary Part, GM	.161892	.000000	
Total, Gm/Bhp-Hr	.52	.00	.52
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	3.952
Lbs/Bhp-Hr	.000	.000	.375
Lbs/Measured	4.465	.000	
BRAKE HORSEPOWER-HOUR	10.541	.000	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	0
Slope	.99512	.00000
(Limit: 0.97-1.03)		
Y-Intercept	14.161	.000
(Limit: +-50 RPM)		
Std Error	17.521	.000
(Limit: 100 RPM)		
R-Square	.99880	.00000
(Limit: 0.97)		
TORQUE		
Number	997	0
Slope	.99618	.00000
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-5.362	.000
(Limit: +-15 Ft-Lbs)		
Std Error	5.164%	.000%
(Limit: 13% Max Eng Tq)		
R-Square	.96518	.00000
(Limit: 0.85/0.88)		
POWER		
Number	997	0
Slope	.99382	.00000
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-1.645	.000
(Limit: +-5 BHP)		
Std Error	5.727%	.000%
(Limit: 8%)		
R-Square	.96853	.00000
(Limit: 0.91)		
WORK		
Actual	10.541	.000
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	10.733	.000
% Difference	-1.79%	.00%

DIESEL SUMMARY REPORT

Test Number: HD-910260 Manufacturer: EXPERIMENTAL
Test Date/Time: 8-28-91 8:45 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA

Barometer: 29.25 "HG
Dry Bulb Temperature: 84.70 F
Absolute Humidity: 63.63 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	4.38	
Exhaust+Bkg, Gm	.00	10.77	
Net, Gm/Bhp-Hr	.000	.000	.778
CO (BAG)			
Background, PPM	.00	3.09	
Exhaust+Bkg, Gm	.00	38.13	
Net, Gm/Bhp-Hr	.00	.00	3.29
NOX (INTEGRATED)			
Background, PPM	.00	1.00	
Exhaust+Bkg, Gm	.00	120.21	
Net, Gm/Bhp-Hr	.000	.000	10.994
CO2 (BAG)			
Background, PPM	.000	.037	
Exhaust+Bkg, Gm	.00	6221.32	
Net, Gm/Bhp-Hr	.0	.0	527.1
PARTICULATE			
Secondary Tare, GM	.000000	.159493	
Secondary Part, GM	.000000	.159649	
Primary Tare, GM	.000000	.151627	
Primary Part, GM	.000000	.155020	
Total, Gm/Bhp-Hr	.00	.38	.38
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	3.793
Lbs/Bhp-Hr	.000	.000	.363
Lbs/Measured	.000	4.111	
BRAKE HORSEPOWER-HOUR	.000	10.443	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99461	.99461
(Limit: 0.97-1.03)		
Y-Intercept	13.637	13.637
(Limit: +-50 RPM)		
Std Error	17.833	17.833
(Limit: 100 RPM)		
R-Square	.99876	.99876
(Limit: 0.97)		
TORQUE		
Number	997	997
Slope	.99610	.99610
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-6.974	-6.974
(Limit: +-15 Ft-Lbs)		
Std Error	5.608%	5.608%
(Limit: 13% Max Eng Tq)		
R-Square	.95918	.95918
(Limit: 0.85/0.88)		
POWER		
Number	997	997
Slope	.99473	.99473
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-2.248	-2.248
(Limit: +-5 BHP)		
Std Error	6.322%	6.322%
(Limit: 8%)		
R-Square	.96197	.96197
(Limit: 0.91)		
WORK		
Actual	.000	10.443
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	10.733
% Difference	.00%	-2.70%

JOHN DEERE 6068T PRODUCTION ENGINE TRANSIENT TEST #2
HOT START #1

DIESEL SUMMARY REPORT

JOHN DEERE 6068T PRODUCTION ENGINE TRANSIENT TEST #2
HOT START #2

Test Number: HD-910261 Manufacturer: EXPERIMENTAL
Test Date/Time: 8-28-91 9:26 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA

Barometer: 29.25 "HG
Dry Bulb Temperature: 84.40 F
Absolute Humidity: 62.46 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	4.38	
Exhaust+Bkg, Gm	.00	10.44	
Net, Gm/Bhp-Hr	.000	.000	.747
CO (BAG)			
Background, PPM	.00	2.87	
Exhaust+Bkg, Gm	.00	38.98	
Net, Gm/Bhp-Hr	.00	.00	3.40
NOX (INTEGRATED)			
Background, PPM	.00	1.00	
Exhaust+Bkg, Gm	.00	118.29	
Net, Gm/Bhp-Hr	.000	.000	10.789
CO2 (BAG)			
Background, PPM	.000	.037	
Exhaust+Bkg, Gm	.00	6103.57	
Net, Gm/Bhp-Hr	.0	.0	515.8
PARTICULATE			
Secondary Tare, GM	.000000	.158496	
Secondary Part, GM	.000000	.158644	
Primary Tare, GM	.000000	.153243	
Primary Part, GM	.000000	.156705	
Total, Gm/Bhp-Hr	.00	.39	.39
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	3.711
Lbs/Bhp-Hr	.000	.000	.356
Lbs/Measured	.000	4.040	
BRAKE HORSEPOWER-HOUR	.000	10.438	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99439	.99439
(Limit: 0.97-1.03)		
Y-Intercept	13.617	13.617
(Limit: +-50 RPM)		
Std Error	18.083	18.083
(Limit: 100 RPM)		
R-Square	.99872	.99872
(Limit: 0.97)		
TORQUE		
Number	997	997
Slope	.99506	.99506
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-6.887	-6.887
(Limit: +-15 Ft-Lbs)		
Std Error	5.717%	5.717%
(Limit: 13% Max Eng Tq)		
R-Square	.95757	.95757
(Limit: 0.85/0.88)		
POWER		
Number	997	997
Slope	.99330	.99330
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-2.226	-2.226
(Limit: +-5 BHP)		
Std Error	6.449%	6.449%
(Limit: 8%)		
R-Square	.96038	.96038
(Limit: 0.91)		
WORK		
Actual	.000	10.438
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	10.733
% Difference	.00%	-2.75%

DIESEL SUMMARY REPORT

Test Number: HD-910263 Manufacturer: EXPERIMENTAL
Test Date/Time: 9- 4-91 13:30 Engine ID: 999 JD 6068H 07620 0

AMBIENT DATA

Barometer: 29.11 "HG
Dry Bulb Temperature: 85.40 F
Absolute Humidity: 58.69 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	2.89	.00	
Exhaust+Bkg, Gm	12.78	.00	
Net, Gm/Bhp-Hr	.000	.000	.976
CO (BAG)			
Background, PPM	.59	.00	
Exhaust+Bkg, Gm	40.68	.00	
Net, Gm/Bhp-Hr	.00	.00	3.53
NOX (INTEGRATED)			
Background, PPM	.26	.00	
Exhaust+Bkg, Gm	73.54	.00	
Net, Gm/Bhp-Hr	.000	.000	6.193
CO2 (BAG)			
Background, PPM	.036	.000	
Exhaust+Bkg, Gm	7070.72	.00	
Net, Gm/Bhp-Hr	.0	.0	565.2
PARTICULATE			
Secondary Tare, GM	.157221	.000000	
Secondary Part, GM	.157871	.000000	
Primary Tare, GM	.151937	.000000	
Primary Part, GM	.156243	.000000	
Total, Gm/Bhp-Hr	.44	.00	.44
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	4.409
Lbs/Bhp-Hr	.000	.000	.390
Lbs/Measured	4.820	.000	
BRAKE HORSEPOWER-HOUR	11.312	.000	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	0
Slope	.99639	.00000
(Limit: 0.97-1.03)		
Y-Intercept	15.254	.000
(Limit: +-50 RPM)		
Std Error	31.385	.000
(Limit: 100 RPM)		
R-Square	.99684	.00000
(Limit: 0.97)		
TORQUE		
Number	994	0
Slope	1.00483	.00000
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-2.714	.000
(Limit: +-15 Ft-Lbs)		
Std Error	6.814%	.000%
(Limit: 13% Max Eng Tq)		
R-Square	.95077	.00000
(Limit: 0.85/0.88)		
POWER		
Number	994	0
Slope	1.00876	.00000
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-.908	.000
(Limit: +-5 BHP)		
Std Error	6.740%	.000%
(Limit: 8%)		
R-Square	.95655	.00000
(Limit: 0.91)		
WORK		
Actual	11.312	.000
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	11.219	.000
% Difference	.83%	.00%

JOHN DEERE 6068H PROTOTYPE ENGINE TRANSIENT TEST #1
COLD START

DIESEL SUMMARY REPORT

Test Number: HD-910264 Manufacturer: EXPERIMENTAL
Test Date/Time: 9- 4-91 14:10 Engine ID: 999 JD 6068H 07620 0

AMBIENT DATA

Barometer: 29.09 "HG
Dry Bulb Temperature: 87.50 F
Absolute Humidity: 54.47 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	3.48	
Exhaust+Bkg, Gm	.00	10.01	
Net, Gm/Bhp-Hr	.000	.000	.703
CO (BAG)			
Background, PPM	.00	.69	
Exhaust+Bkg, Gm	.00	27.78	
Net, Gm/Bhp-Hr	.00	.00	2.39
NOX (INTEGRATED)			
Background, PPM	.00	.26	
Exhaust+Bkg, Gm	.00	72.93	
Net, Gm/Bhp-Hr	.000	.000	6.096
CO2 (BAG)			
Background, PPM	.000	.036	
Exhaust+Bkg, Gm	.00	6662.35	
Net, Gm/Bhp-Hr	.0	.0	530.8
PARTICULATE			
Secondary Tare, GM	.000000	.158947	
Secondary Part, GM	.000000	.159255	
Primary Tare, GM	.000000	.158042	
Primary Part, GM	.000000	.161185	
Total, Gm/Bhp-Hr	.00	.32	.32
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	4.112
Lbs/Bhp-Hr	.000	.000	.365
Lbs/Measured	.000	4.465	
BRAKE HORSEPOWER-HOUR	.000	11.279	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99615	.99615
(Limit: 0.97-1.03)		
Y-Intercept	15.022	15.022
(Limit: +-50 RPM)		
Std Error	31.401	31.401
(Limit: 100 RPM)		
R-Square	.99683	.99683
(Limit: 0.97)		
TORQUE		
Number	994	994
Slope	1.00784	1.00784
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-4.053	-4.053
(Limit: +-15 Ft-Lbs)		
Std Error	6.983%	6.983%
(Limit: 13% Max Eng Tq)		
R-Square	.94871	.94871
(Limit: 0.85/0.88)		
POWER		
Number	994	994
Slope	1.00768	1.00768
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-1.194	-1.194
(Limit: +-5 BHP)		
Std Error	6.822%	6.822%
(Limit: 8%)		
R-Square	.95545	.95545
(Limit: 0.91)		
WORK		
Actual	.000	11.279
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	11.219
% Difference	.00%	.53%

JOHN DEERE 6068H PROTOTYPE ENGINE TRANSIENT TEST #1
HOT START #1

DIESEL SUMMARY REPORT

JOHN DEERE 6068H PROTOTYPE ENGINE TRANSIENT TEST #1
HOT START #2

Test Number: HD-910265 Manufacturer: EXPERIMENTAL
Test Date/Time: 9- 4-91 14:50 Engine ID: 999 JD 6068H 07620 0

AMBIENT DATA

Barometer: 29.08 "HG
Dry Bulb Temperature: 87.10 F
Absolute Humidity: 54.70 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	3.63	
Exhaust+Bkg, Gm	.00	10.04	
Net, Gm/Bhp-Hr	.000	.000	.696
CO (BAG)			
Background, PPM	.00	.78	
Exhaust+Bkg, Gm	.00	28.05	
Net, Gm/Bhp-Hr	.00	.00	2.40
NOX (INTEGRATED)			
Background, PPM	.00	.26	
Exhaust+Bkg, Gm	.00	71.02	
Net, Gm/Bhp-Hr	.000	.000	5.924
CO2 (BAG)			
Background, PPM	.000	.036	
Exhaust+Bkg, Gm	.00	6667.67	
Net, Gm/Bhp-Hr	.0	.0	529.9
PARTICULATE			
Secondary Tare, GM	.000000	.158451	
Secondary Part, GM	.000000	.158658	
Primary Tare, GM	.000000	.158284	
Primary Part, GM	.000000	.161449	
Total, Gm/Bhp-Hr	.00	.31	.31
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	4.115
Lbs/Bhp-Hr	.000	.000	.364
Lbs/Measured	.000	4.465	
BRAKE HORSEPOWER-HOUR	.000	11.306	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99602	.99602
(Limit: 0.97-1.03)		
Y-Intercept	15.054	15.054
(Limit: +-50 RPM)		
Std Error	31.922	31.922
(Limit: 100 RPM)		
R-Square	.99672	.99672
(Limit: 0.97)		
TORQUE		
Number	994	994
Slope	1.00833	1.00833
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-4.041	-4.041
(Limit: +-15 Ft-Lbs)		
Std Error	7.057%	7.057%
(Limit: 13% Max Eng Tq)		
R-Square	.94773	.94773
(Limit: 0.85/0.88)		
POWER		
Number	994	994
Slope	1.00838	1.00838
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-1.191	-1.191
(Limit: +-5 BHP)		
Std Error	6.815%	6.815%
(Limit: 8%)		
R-Square	.95559	.95559
(Limit: 0.91)		
WORK		
Actual	.000	11.306
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	11.219
% Difference	.00%	.78%

DIESEL SUMMARY REPORT

Test Number: HD-910266 Manufacturer: EXPERIMENTAL
Test Date/Time: 9- 5-91 8: 6 Engine ID: 999 JD 6068H 07620 0

AMBIENT DATA

Barometer: 29.19 "HG
Dry Bulb Temperature: 87.50 F
Absolute Humidity: 53.47 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	3.63	.00	
Exhaust+Bkg, Gm	13.03	.00	
Net, Gm/Bhp-Hr	.000	.000	.960
CO (BAG)			
Background, PPM	1.08	.00	
Exhaust+Bkg, Gm	43.00	.00	
Net, Gm/Bhp-Hr	.00	.00	3.69
NOX (INTEGRATED)			
Background, PPM	1.03	.00	
Exhaust+Bkg, Gm	77.61	.00	
Net, Gm/Bhp-Hr	.000	.000	6.332
CO2 (BAG)			
Background, PPM	.042	.000	
Exhaust+Bkg, Gm	7167.81	.00	
Net, Gm/Bhp-Hr	.0	.0	564.4
PARTICULATE			
Secondary Tare, GM	.151576	.000000	
Secondary Part, GM	.151962	.000000	
Primary Tare, GM	.152028	.000000	
Primary Part, GM	.156593	.000000	
Total, Gm/Bhp-Hr	.44	.00	.44
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	4.400
Lbs/Bhp-Hr	.000	.000	.389
Lbs/Measured	4.891	.000	
BRAKE HORSEPOWER-HOUR	11.300	.000	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	0
Slope	.99647	.00000
(Limit: 0.97-1.03)		
Y-Intercept	15.390	.000
(Limit: +-50 RPM)		
Std Error	31.812	.000
(Limit: 100 RPM)		
R-Square	.99675	.00000
(Limit: 0.97)		
TORQUE		
Number	994	0
Slope	1.00406	.00000
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-2.919	.000
(Limit: +-15 Ft-Lbs)		
Std Error	6.761%	.000%
(Limit: 13% Max Eng Tq)		
R-Square	.95142	.00000
(Limit: 0.85/0.88)		
POWER		
Number	994	0
Slope	1.00635	.00000
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-.921	.000
(Limit: +-5 BHP)		
Std Error	6.701%	.000%
(Limit: 8%)		
R-Square	.95684	.00000
(Limit: 0.91)		
WORK		
Actual	11.300	.000
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	11.219	.000
% Difference	.72%	.00%

JOHN DEERE 6068H PROTOTYPE ENGINE TRANSIENT TEST #2
COLD START

DIESEL SUMMARY REPORT

JOHN DEERE 6068H PROTOTYPE ENGINE TRANSIENT TEST #2
HOT START #1

Test Number: HD-910267 Manufacturer: EXPERIMENTAL
Test Date/Time: 9- 5-91 8:47 Engine ID: 999 JD 6068H 07620 0

AMBIENT DATA

Barometer: 29.16 "HG
Dry Bulb Temperature: 88.20 F
Absolute Humidity: 53.93 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	4.15	
Exhaust+Bkg, Gm	.00	10.15	
Net, Gm/Bhp-Hr	.000	.000	.678
CO (BAG)			
Background, PPM	.00	.78	
Exhaust+Bkg, Gm	.00	28.13	
Net, Gm/Bhp-Hr	.00	.00	2.41
NOX (INTEGRATED)			
Background, PPM	.00	.77	
Exhaust+Bkg, Gm	.00	73.32	
Net, Gm/Bhp-Hr	.000	.000	6.028
CO2 (BAG)			
Background, PPM	.000	.040	
Exhaust+Bkg, Gm	.00	6765.37	
Net, Gm/Bhp-Hr	.0	.0	532.8
PARTICULATE			
Secondary Tare, GM	.000000	.159060	
Secondary Part, GM	.000000	.159347	
Primary Tare, GM	.000000	.157641	
Primary Part, GM	.000000	.161019	
Total, Gm/Bhp-Hr	.00	.34	.34
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	4.131
Lbs/Bhp-Hr	.000	.000	.366
Lbs/Measured	.000	4.465	
BRAKE HORSEPOWER-HOUR	.000	11.290	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99610	.99610
(Limit: 0.97-1.03)		
Y-Intercept	15.093	15.093
(Limit: +-50 RPM)		
Std Error	31.922	31.922
(Limit: 100 RPM)		
R-Square	.99673	.99673
(Limit: 0.97)		
TORQUE		
Number	995	995
Slope	1.00939	1.00939
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-4.368	-4.368
(Limit: +-15 Ft-Lbs)		
Std Error	6.962%	6.962%
(Limit: 13% Max Eng Tq)		
R-Square	.94935	.94935
(Limit: 0.85/0.88)		
POWER		
Number	995	995
Slope	1.00884	1.00884
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-1.219	-1.219
(Limit: +-5 BHP)		
Std Error	6.788%	6.788%
(Limit: 8%)		
R-Square	.95616	.95616
(Limit: 0.91)		
WORK		
Actual	.000	11.290
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	11.219
% Difference	.00%	.63%

DIESEL SUMMARY REPORT

Test Number: HD-910268 Manufacturer: EXPERIMENTAL
Test Date/Time: 9- 5-91 9:27 Engine ID: 999 JD 6068H 07620 0

AMBIENT DATA

Barometer: 29.16 "HG
Dry Bulb Temperature: 88.50 F
Absolute Humidity: 54.55 Grains H2O / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	4.15	
Exhaust+Bkg, Gm	.00	10.00	
Net, Gm/Bhp-Hr	.000	.000	.665
CO (BAG)			
Background, PPM	.00	.78	
Exhaust+Bkg, Gm	.00	28.07	
Net, Gm/Bhp-Hr	.00	.00	2.40
NOX (INTEGRATED)			
Background, PPM	.00	.77	
Exhaust+Bkg, Gm	.00	72.65	
Net, Gm/Bhp-Hr	.000	.000	5.983
CO2 (BAG)			
Background, PPM	.000	.040	
Exhaust+Bkg, Gm	.00	6779.71	
Net, Gm/Bhp-Hr	.0	.0	534.2
PARTICULATE			
Secondary Tare, GM	.000000	.159701	
Secondary Part, GM	.000000	.159964	
Primary Tare, GM	.000000	.151494	
Primary Part, GM	.000000	.154824	
Total, Gm/Bhp-Hr	.00	.33	.33
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	4.139
Lbs/Bhp-Hr	.000	.000	.367
Lbs/Measured	.000	4.607	
BRAKE HORSEPOWER-HOUR	.000	11.286	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99575	.99575
(Limit: 0.97-1.03)		
Y-Intercept	15.024	15.024
(Limit: +-50 RPM)		
Std Error	31.765	31.765
(Limit: 100 RPM)		
R-Square	.99675	.99675
(Limit: 0.97)		
TORQUE		
Number	995	995
Slope	1.00742	1.00742
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-4.075	-4.075
(Limit: +-15 Ft-Lbs)		
Std Error	7.031%	7.031%
(Limit: 13% Max Eng Tq)		
R-Square	.94819	.94819
(Limit: 0.85/0.88)		
POWER		
Number	995	995
Slope	1.00692	1.00692
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-1.178	-1.178
(Limit: +-5 BHP)		
Std Error	6.840%	6.840%
(Limit: 8%)		
R-Square	.95534	.95534
(Limit: 0.91)		
WORK		
Actual	.000	11.286
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	11.219
% Difference	.00%	.60%

JOHN DEERE 6068H PROTOTYPE ENGINE TRANSIENT TEST #2
HOT START #2

DIESEL SUMMARY REPORT

FORD NEW HOLLAND PRODUCTION ENGINE TRANSIENT TEST #1
COLD START

Test Number: HD-910332 Manufacturer: FORD
Test Date/Time: 11- 7-91 8:36 Engine ID: 30 NH358-117-91-89V 0

AMBIENT DATA

Barometer: 29.35 "HG
Dry Bulb Temperature: 74.60 F
Absolute Humidity: 70.83 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	3.33	.00	
Exhaust+Bkg, Gm	29.90	.00	
Net, Gm/Bhp-Hr	.000	.000	3.326
CO (BAG)			
Background, PPM	1.72	.00	
Exhaust+Bkg, Gm	60.69	.00	
Net, Gm/Bhp-Hr	.00	.00	6.99
NOX (INTEGRATED)			
Background, PPM	.50	.00	
Exhaust+Bkg, Gm	87.09	.00	
Net, Gm/Bhp-Hr	.000	.000	10.162
CO2 (BAG)			
Background, PPM	.026	.000	
Exhaust+Bkg, Gm	5879.32	.00	
Net, Gm/Bhp-Hr	.0	.0	642.8
PARTICULATE			
Secondary Tare, GM	.156085	.000000	
Secondary Part, GM	.156391	.000000	
Primary Tare, GM	.156485	.000000	
Primary Part, GM	.167186	.000000	
Total, Gm/Bhp-Hr	1.24	.00	1.24
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	3.782
Lbs/Bhp-Hr	.000	.000	.451
Lbs/Measured	4.324	.000	
BRAKE HORSEPOWER-HOUR	8.380	.000	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	0
Slope	.99897	.00000
(Limit: 0.97-1.03)		
Y-Intercept	-21.196	.000
(Limit: +-50 RPM)		
Std Error	14.697	.000
(Limit: 100 RPM)		
R-Square	.99932	.00000
(Limit: 0.97)		
TORQUE		
Number	866	0
Slope	.96887	.00000
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-4.184	.000
(Limit: +-15 Ft-Lbs)		
Std Error	7.332%	.000%
(Limit: 13% Max Eng Tq)		
R-Square	.93436	.00000
(Limit: 0.85/0.88)		
POWER		
Number	866	0
Slope	.97399	.00000
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-1.574	.000
(Limit: +-5 BHP)		
Std Error	5.825%	.000%
(Limit: 8%)		
R-Square	.95191	.00000
(Limit: 0.91)		
WORK		
Actual	8.380	.000
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	9.341	.000
% Difference	-10.29%	.00%

DIESEL SUMMARY REPORT

Test Number: HD-910333 Manufacturer: FORD
Test Date/Time: 11- 7-91 9:17 Engine ID: 30 NH358-117-91-89V 0

AMBIENT DATA

Barometer: 29.33 "HG
Dry Bulb Temperature: 76.40 F
Absolute Humidity: 78.22 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	3.90	
Exhaust+Bkg, Gm	.00	24.62	
Net, Gm/Bhp-Hr	.000	.000	2.593
CO (BAG)			
Background, PPM	.00	1.07	
Exhaust+Bkg, Gm	.00	52.35	
Net, Gm/Bhp-Hr	.00	.00	5.95
NOX (INTEGRATED)			
Background, PPM	.00	1.03	
Exhaust+Bkg, Gm	.00	83.94	
Net, Gm/Bhp-Hr	.000	.000	9.622
CO2 (BAG)			
Background, PPM	.000	.026	
Exhaust+Bkg, Gm	.00	5679.04	
Net, Gm/Bhp-Hr	.0	.0	604.1
PARTICULATE			
Secondary Tare, GM	.000000	.157945	
Secondary Part, GM	.000000	.158216	
Primary Tare, GM	.000000	.158800	
Primary Part, GM	.000000	.168286	
Total, Gm/Bhp-Hr	.00	1.05	1.05
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	3.623
Lbs/Bhp-Hr	.000	.000	.422
Lbs/Measured	.000	3.969	
BRAKE HORSEPOWER-HOUR	.000	8.580	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99736	.99736
(Limit: 0.97-1.03)		
Y-Intercept	-21.589	-21.589
(Limit: +-50 RPM)		
Std Error	14.933	14.933
(Limit: 100 RPM)		
R-Square	.99929	.99929
(Limit: 0.97)		
TORQUE		
Number	901	901
Slope	.96593	.96593
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-3.552	-3.552
(Limit: +-15 Ft-Lbs)		
Std Error	7.699%	7.699%
(Limit: 13% Max Eng Tq)		
R-Square	.93058	.93058
(Limit: 0.85/0.88)		
POWER		
Number	901	901
Slope	.97583	.97583
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-1.725	-1.725
(Limit: +-5 BHP)		
Std Error	6.458%	6.458%
(Limit: 8%)		
R-Square	.94569	.94569
(Limit: 0.91)		
WORK		
Actual	.000	8.580
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	9.341
% Difference	.00%	-8.15%

FORD NEW HOLLAND PRODUCTION ENGINE TRANSIENT TEST #1
HOT START #1

DIESEL SUMMARY REPORT

FORD NEW HOLLAND PRODUCTION ENGINE TRANSIENT TEST #1
HOT START #2

Test Number: HD-910334 Manufacturer: FORD
Test Date/Time: 11- 7-91 10: 0 Engine ID: 30 NH358-117-91-89V 0

AMBIENT DATA

Barometer: 29.33 "HG
Dry Bulb Temperature: 76.00 F
Absolute Humidity: 99.12 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	4.65	
Exhaust+Bkg, Gm	.00	22.83	
Net, Gm/Bhp-Hr	.000	.000	2.328
CO (BAG)			
Background, PPM	.00	1.07	
Exhaust+Bkg, Gm	.00	52.32	
Net, Gm/Bhp-Hr	.00	.00	5.94
NOX (INTEGRATED)			
Background, PPM	.00	.00	
Exhaust+Bkg, Gm	.00	80.64	
Net, Gm/Bhp-Hr	.000	.000	10.013
CO2 (BAG)			
Background, PPM	.000	.026	
Exhaust+Bkg, Gm	.00	5676.05	
Net, Gm/Bhp-Hr	.0	.0	602.8
PARTICULATE			
Secondary Tare, GM	.000000	.158290	
Secondary Part, GM	.000000	.158484	
Primary Tare, GM	.000000	.158525	
Primary Part, GM	.000000	.167544	
Total, Gm/Bhp-Hr	.00	1.01	1.01
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	3.616
Lbs/Bhp-Hr	.000	.000	.421
Lbs/Measured	.000	3.898	
BRAKE HORSEPOWER-HOUR	.000	8.593	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99638	.99638
(Limit: 0.97-1.03)		
Y-Intercept	-21.797	-21.797
(Limit: +-50 RPM)		
Std Error	14.663	14.663
(Limit: 100 RPM)		
R-Square	.99932	.99932
(Limit: 0.97)		
TORQUE		
Number	902	902
Slope	.96791	.96791
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-3.733	-3.733
(Limit: +-15 Ft-Lbs)		
Std Error	7.912%	7.912%
(Limit: 13% Max Eng Tq)		
R-Square	.92760	.92760
(Limit: 0.85/0.88)		
POWER		
Number	902	902
Slope	.97609	.97609
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-1.776	-1.776
(Limit: +-5 BHP)		
Std Error	6.622%	6.622%
(Limit: 8%)		
R-Square	.94365	.94365
(Limit: 0.91)		
WORK		
Actual	.000	8.593
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	9.341
% Difference	.00%	-8.01%

DIESEL SUMMARY REPORT

FORD NEW HOLLAND PRODUCTION ENGINE TRANSIENT TEST #2
COLD START

Test Number: HD-910366 Manufacturer: FORD
Test Date/Time: 11-12-91 10:23 Engine ID: 30 NH358-117-91-89V 0

AMBIENT DATA

Barometer: 29.14 "HG
Dry Bulb Temperature: 73.60 F
Absolute Humidity: 64.83 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	3.33	.00	
Exhaust+Bkg, Gm	27.11	.00	
Net, Gm/Bhp-Hr	.000	.000	2.925
CO (BAG)			
Background, PPM	1.93	.00	
Exhaust+Bkg, Gm	67.93	.00	
Net, Gm/Bhp-Hr	.00	.00	7.64
NOX (INTEGRATED)			
Background, PPM	.50	.00	
Exhaust+Bkg, Gm	94.44	.00	
Net, Gm/Bhp-Hr	.000	.000	10.606
CO2 (BAG)			
Background, PPM	.039	.000	
Exhaust+Bkg, Gm	6475.50	.00	
Net, Gm/Bhp-Hr	.0	.0	667.9
PARTICULATE			
Secondary Tare, GM	.158902	.000000	
Secondary Part, GM	.159117	.000000	
Primary Tare, GM	.158151	.000000	
Primary Part, GM	.164280	.000000	
Total, Gm/Bhp-Hr	1.07	.00	1.07
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	4.018
Lbs/Bhp-Hr	.000	.000	.468
Lbs/Measured	4.395	.000	
BRAKE HORSEPOWER-HOUR	8.584	.000	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	0
Slope	.99608	.00000
(Limit: 0.97-1.03)		
Y-Intercept	-21.582	.000
(Limit: +-50 RPM)		
Std Error	14.629	.000
(Limit: 100 RPM)		
R-Square	.99932	.00000
(Limit: 0.97)		
TORQUE		
Number	869	0
Slope	1.00058	.00000
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-5.958	.000
(Limit: +-15 Ft-Lbs)		
Std Error	7.836%	.000%
(Limit: 13% Max Eng Tq)		
R-Square	.92786	.00000
(Limit: 0.85/0.88)		
POWER		
Number	869	0
Slope	1.00142	.00000
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-1.780	.000
(Limit: +-5 BHP)		
Std Error	5.938%	.000%
(Limit: 8%)		
R-Square	.95168	.00000
(Limit: 0.91)		
WORK		
Actual	8.584	.000
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	9.341	.000
% Difference	-8.10%	.00%

DIESEL SUMMARY REPORT

Test Number: HD-910367 Manufacturer: FORD
Test Date/Time: 11-12-91 11: 5 Engine ID: 30 NH358-117-91-89V 0

AMBIENT DATA

Barometer: 29.14 "HG
Dry Bulb Temperature: 75.00 F
Absolute Humidity: 45.29 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	4.20	
Exhaust+Bkg, Gm	.00	22.84	
Net, Gm/Bhp-Hr	.000	.000	2.366
CO (BAG)			
Background, PPM	.00	1.93	
Exhaust+Bkg, Gm	.00	55.91	
Net, Gm/Bhp-Hr	.00	.00	6.24
NOX (INTEGRATED)			
Background, PPM	.00	.26	
Exhaust+Bkg, Gm	.00	87.87	
Net, Gm/Bhp-Hr	.000	.000	9.447
CO2 (BAG)			
Background, PPM	.000	.035	
Exhaust+Bkg, Gm	.00	5986.42	
Net, Gm/Bhp-Hr	.0	.0	620.1
PARTICULATE			
Secondary Tare, GM	.000000	.156185	
Secondary Part, GM	.000000	.156305	
Primary Tare, GM	.000000	.154854	
Primary Part, GM	.000000	.159978	
Total, Gm/Bhp-Hr	.00	.97	.97
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	3.716
Lbs/Bhp-Hr	.000	.000	.433
Lbs/Measured	.000	3.969	
BRAKE HORSEPOWER-HOUR	.000	8.584	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99545	.99545
(Limit: 0.97-1.03)		
Y-Intercept	-22.124	-22.124
(Limit: +-50 RPM)		
Std Error	14.731	14.731
(Limit: 100 RPM)		
R-Square	.99931	.99931
(Limit: 0.97)		
TORQUE		
Number	895	895
Slope	.99541	.99541
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-6.840	-6.840
(Limit: +-15 Ft-Lbs)		
Std Error	8.255%	8.255%
(Limit: 13% Max Eng Tq)		
R-Square	.92423	.92423
(Limit: 0.85/0.88)		
POWER		
Number	895	895
Slope	.99696	.99696
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-2.136	-2.136
(Limit: +-5 BHP)		
Std Error	6.439%	6.439%
(Limit: 8%)		
R-Square	.94702	.94702
(Limit: 0.91)		
WORK		
Actual	.000	8.584
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	9.341
% Difference	.00%	-8.10%

FORD NEW HOLLAND PRODUCTION ENGINE TRANSIENT TEST #2
HOT START #1

DIESEL SUMMARY REPORT

Test Number: HD-910368 Manufacturer: FORD
Test Date/Time: 11-12-91 11:48 Engine ID: 30 NH358-117-91-89V 0

AMBIENT DATA

Barometer: 29.15 "HG
Dry Bulb Temperature: 75.10 F
Absolute Humidity: 49.07 Grains H20 / Lb. Dry Air

EMISSION RESULTS	CS	HS	WTD TEST
HC (INTEGRATED)			
Background, PPM	.00	4.50	
Exhaust+Bkg, Gm	.00	21.95	
Net, Gm/Bhp-Hr	.000	.000	2.245
CO (BAG)			
Background, PPM	.00	1.72	
Exhaust+Bkg, Gm	.00	55.06	
Net, Gm/Bhp-Hr	.00	.00	6.18
NOX (INTEGRATED)			
Background, PPM	.00	.26	
Exhaust+Bkg, Gm	.00	85.90	
Net, Gm/Bhp-Hr	.000	.000	9.333
CO2 (BAG)			
Background, PPM	.000	.035	
Exhaust+Bkg, Gm	.00	5908.16	
Net, Gm/Bhp-Hr	.0	.0	611.7
PARTICULATE			
Secondary Tare, GM	.000000	.157950	
Secondary Part, GM	.000000	.158122	
Primary Tare, GM	.000000	.157194	
Primary Part, GM	.000000	.162804	
Total, Gm/Bhp-Hr	.00	.99	.99
FUEL CONSUMPTION			
Lbs/Carbon Balance	.000	.000	3.659
Lbs/Bhp-Hr	.000	.000	.427
Lbs/Measured	.000	3.969	
BRAKE HORSEPOWER-HOUR	.000	8.571	

CYCLE STATISTICS	CS	HS
SPEED		
Number	1175	1175
Slope	.99480	.99480
(Limit: 0.97-1.03)		
Y-Intercept	-21.948	-21.948
(Limit: +-50 RPM)		
Std Error	14.629	14.629
(Limit: 100 RPM)		
R-Square	.99932	.99932
(Limit: 0.97)		
TORQUE		
Number	885	885
Slope	.99798	.99798
(Limit: 0.77/0.83-1.03)		
Y-Intercept	-6.624	-6.624
(Limit: +-15 Ft-Lbs)		
Std Error	7.403%	7.403%
(Limit: 13% Max Eng Tq)		
R-Square	.93785	.93785
(Limit: 0.85/0.88)		
POWER		
Number	885	885
Slope	.99584	.99584
(Limit: 0.87/0.89-1.03)		
Y-Intercept	-2.046	-2.046
(Limit: +-5 BHP)		
Std Error	6.068%	6.068%
(Limit: 8%)		
R-Square	.95163	.95163
(Limit: 0.91)		
WORK		
Actual	.000	8.571
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	9.341
% Difference	.00%	-8.24%

FORD NEW HOLLAND PRODUCTION ENGINE TRANSIENT TEST #2
HOT START #2

C. Raw 8-Mode Steady-State Test Emission Data

Table C.1
JOHN DEERE 6068T PRODUCTION ENGINE 8-MODE STEADY STATE #1

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	8/26	1991						
Speed, rpm	1300	1300	1300	2200	2200	2200	2200	960
Torque, Ft-lb	240	360	480	335	251	168	34	0
Power, Hp	58.0	87.1	116.9	138.0	103.9	68.0	14.9	0
Water In, deg F	146.9	147.2	147.2	147.2	147.2	147.2	146.9	145.2
Water Out, deg F	172.8	177.6	178.9	179.7	177.1	174.9	171.9	168.0
Oil, deg F	185.0	189.3	198.5	202.0	198.5	193.2	186.7	172.3
Inlet Air, deg F	87.1	86.8	88.2	87.5	87.8	87.8	86.5	86.1
Fuel, deg F	93.3	90.9	90.9	91.1	93.6	95.0	94.3	93.6
Fuel Return, deg F	122.2	122.2	122.2	122.6	122.6	122.6	122.6	122.2
Exhaust, deg F	564.6	729.2	880.5	786.7	703.4	604.5	393.2	199.3
Inlet Restriction in H2O	2.0	2.4	2.9	9.9	8.2	6.7	5.3	1.0
Exhaust Restriction in Hg	0.2	0.4	0.6	2.4	1.8	1.3	0.8	0.1
Fuel Flow, gal/hour	3.0	4.2	5.7	7.2	5.7	3.9	1.8	0.3
Sample Zone Temp, deg F	109.1	121.0	140.9	193.5	166.9	141.6	108.4	80.3
Filter Face Temp, deg F	104.6	105.6	114.5	124.5	120.0	111.5	101.9	87.1
Total Tunnel Flow, ft^3	28040	27790	18270	17660	26990	27420	28090	38310
Exhaust HC, ppm	13.79	15.24	11.83	20.54	16.14	23.97	36.20	13.84
Exhaust NO_x, ppm	139.6	217.8	276.5	290.5	175.8	94.10	27.52	10.99
Exhaust CO_2, %	0.457	0.710	0.961	1.219	0.959	0.685	0.293	0.064
Exhaust CO, ppm	6.95	10.14	65.24	189.9	93.95	49.79	30.48	15.79
Background HC, ppm	3.78	4.23	4.60	4.45	4.15	4.52	4.75	4.30
Background NO_x, ppm	0.50	1.50	2.00	2.00	2.00	1.50	1.50	0.50
Background CO_2, %	0.037	0.037	0.039	0.041	0.039	0.037	0.037	0.035
Background CO, ppm	2.64	3.09	3.31	4.41	3.31	3.31	3.31	3.09
Stabilization Time, min	5.75	11	8.33	6.5	6	5	5	7
Collection Time, min	15	15	6.5	10	15	15	15	10

Table C.2
JOHN DEERE 6068T PRODUCTION ENGINE 8-MODE STEADY-STATE #2

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	8/27	1991						
Speed, rpm	1300	1300	1300	2200	2200	2200	2200	960
Torque, Ft-lb	240	360	480	335	251	168	34	0
Power, Hp	59.8	86.7	119.0	137.9	100.9	67.9	12.1	0.1
Water In, deg F	146.6	147.2	147.6	147.9	146.9	146.9	146.6	144.6
Water Out, deg F	172.3	176.2	178.9	179.3	176.7	174.5	171.9	168.0
Oil, deg F	193	185.0	192.8	200.9	199.3	193.7	188.0	173.2
Inlet Air, deg F	85.8	86.1	87.0	87.1	87.5	87.5	87.1	86.4
Fuel, deg F	81.0	87.1	89.2	90.9	92.6	94.0	94.0	95.0
Fuel Return, deg F	121.8	121.8	121.8	121.8	122.2	122.2	121.8	122.2
Exhaust, deg F	576.3	735.6	889.3	788.8	692.7	569.9	395.4	195.4
Inlet Restriction in H2O	2.1	2.35	3.0	11.8	8.2	6.6	5.4	0.95
Exhaust Restriction in Hg	0.40	0.55	0.80	2.2	1.8	1.4	0.95	0.15
Fuel Flow, gal/hour	2.7	4.2	6.0	7.2	6.0	3.9	1.8	0.4
Sample Zone Temp, deg F	115.2	118.0	141.6	194.5	170.9	145.6	111.1	83.4
Filter Face Temp, deg F	104.3	104.3	117.6	118.3	121.7	116.7	105.6	89.2
Exhaust HC, ppm	12.16	15.26	10.02	17.78	14.01	22.99	33.10	13.10
Exhaust NO_x, ppm	147.1	226.3	283.4	287.4	166.7	92.57	27.99	10.49
Exhaust CO_2, %	0.488	0.698	0.986	1.241	0.955	0.687	0.298	0.060
Exhaust CO, ppm	6.29	11.17	83.68	194.6	112.3	64.31	27.45	15.30
Background HC, ppm	3.93	4.52	4.30	4.52	4.67	4.52	4.38	5.19
Background NO_x, ppm	0.50	.050	0.50	1.00	1.00	1.00	0.50	0.50
Background CO_2, %	0.039	0.035	0.039	0.043	0.041	0.037	0.026	0.022
Background CO, ppm	2.42	1.76	2.64	3.97	2.42	1.98	1.54	0.88
Stabilization Time, min	3	5	5	5	5	5	5	5
Collection Time, min	15	15	10	10	15	15	15	20

Table C.3
JOHN DEERE 6068H PROTOTYPE ENGINE 8-MODE STEADY-STATE #1

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	8/6	1991						
Speed, rpm	1300	1300	1300	2200	2200	2200	2200	820
Torque, Ft-lb	234.0	351.0	468.0	373.0	280.0	186.5	37.0	0
Power, Hp	57.9	86.9	115.8	156.2	117.3	78.1	15.5	0
Water In, deg F	148.9	148.9	149.2	149.2	148.9	149.2	149.2	148.6
Water Out, deg F	156.6	159.2	161.4	158.8	157.1	155.3	153.1	150.5
Oil, deg F	177.6	177.1	181.5	196.7	193.2	188.0	180.6	152.3
Inlet Air, deg F	74.6	75.3	74.6	74.6	73.2	75.0	73.2	73.9
Fuel, deg F	89.9	94.7	94.7	96.0	90.2	95.4	96.7	94.7
Fuel Return, deg F	146.2	150.5	151.0	151.8	151.8	150.1	152.7	147.0
Exhaust, deg F	515.6	652.2	793.5	671.7	601.4	511.2	326.7	177.6
Intercooler In, deg F	139.6	164.0	199.8	264.5	225.5	187.0	144.4	110.9
Intercooler Out, deg F	102.2	103.9	107.8	131.8	120.5	110.9	103.9	101.3
Inlet Restriction in H_2O	1.6	2.0	2.7	12.2	9.2	6.8	4.6	0.5
Exhaust Restriction in Hg	0.1	0.3	0.5	2.1	1.6	1.0	0.5	0.1
Fuel Flow, gal/hour	3.0	4.2	5.7	7.8	6.0	4.5	1.8	0.3
Boost Pressure, psi	2.5	4.5	7.4	12.5	9.0	5.5	2.0	0.0
Sample Zone Temp, deg F	108.0	123.1	147.2	210.4	175.2	142.3	102.9	75.3
Filter Face Temp, deg F	99.1	110.1	123.4	124.1	115.9	113.5	100.5	81.3
Total Tunnel Flow, ft^3	28120	27890	18270	17600	26930	27540	28330	38620
Exhaust HC, ppm	7.10	6.17	3.88	13.85	13.44	15.48	45.04	9.42
Exhaust NO_x, ppm	86.97	120.7	140.5	125.5	99.44	67.34	24.53	11.53
Exhaust CO_2, %	0.500	0.715	0.990	1.440	1.122	0.778	0.333	0.066
Exhaust CO, ppm	7.16	9.63	48.58	12.32	14.36	25.29	89.50	21.14
Background HC, ppm	4.23	3.86	4.00	4.45	4.38	5.12	4.97	4.30
Background NO_x, ppm	1.28	0.77	1.03	1.54	1.54	1.80	1.03	0.51
Background CO_2, %	0.035	0.037	0.037	0.033	0.039	0.037	0.028	0.028
Background CO, ppm	2.20	1.98	2.20	1.32	1.98	1.98	1.98	1.99
Stabilization Time, min	6.67	6	5	5	5.33	5	5.33	5.33
Collection Time, min	15	15	10	10	15	15	15	20

Table C.4
JOHN DEERE 6068H PROTOTYPE ENGINE 8-MODE STEADY-STATE #2

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	8/7	1991						
Speed, rpm	1300	1300	1300	2200	2200	2200	2200	820
Torque, Ft-lb	234.0	351.0	468.0	373.0	280.0	186.5	37.0	0
Power, Hp	58.2	85.7	115.3	151.2	116.5	77.6	15.2	0
Water In, deg F	148.6	148.9	148.6	149.2	149.2	149.2	144.4	148.6
Water Out, deg F	156.6	159.2	161.9	158.8	157.1	154.9	103.0	150.1
Oil, deg F	178.0	179.7	185.0	193.7	191.1	188.4	181.0	156.6
Inlet Air, deg F	73.9	75.3	75.3	75.3	75.3	75.0	73.9	74.3
Fuel, deg F	95.4	93.6	94.7	90.6	93.6	88.5	96.7	84.4
Fuel Return, deg F	151.0	149.7	151.0	150.1	153.1	144.0	152.3	140.1
Exhaust, deg F	501.3	645.3	789.7	672.1	600.1	512.1	325.4	174.9
Intercooler In, deg F	138.8	163.6	201.1	264.3	255.5	187.1	144.4	110.4
Intercooler Out, deg F	102.6	103.9	108.7	132.7	120.9	111.3	103.0	101.3
Inlet Restriction in H2O	1.7	1.9	2.6	12.1	9.0	6.7	4.6	0.50
Exhaust Restriction in Hg	0.2	0.3	0.5	2.2	1.7	1.1	0.4	0.05
Fuel Flow, gal/hour	2.7	4.2	5.7	7.5	6.3	4.5	1.8	0.6
Boost Pressure, psi	2.5	4.5	7.25	12.5	8.75	5.5	2.0	0.0
Sample Zone Temp, deg F	108.0	122.4	146.9	212.1	177.2	114.6	105.0	76.0
Filter Face Temp, deg F	102.2	109.7	118.3	118.0	114.2	112.0	102.6	83.7
Total Tunnel Flow, ft^3	28160	27880	18270	17580	26910	27520	28320	38660
Exhaust HC, ppm	6.83	5.32	3.76	12.89	14.22	14.63	43.81	9.72
Exhaust NO_x, ppm	83.98	120.2	140.5	125.9	98.4	68.81	24.28	10.76
Exhaust CO_2, %	0.484	0.716	0.992	1.449	1.108	0.786	0.326	0.058
Exhaust CO, ppm	8.26	8.97	51.14	12.77	14.72	24.73	88.26	22.78
Background HC, ppm	5.12	4.60	4.38	5.19	6.38	5.86	6.31	4.38
Background NO_x, ppm	0.77	0.51	0.51	0.77	0.51	0.77	1.28	0.00
Background CO_2, %	0.032	0.033	0.035	0.032	0.030	0.026	0.022	0.0
Background CO, ppm	1.98	2.20	2.42	1.32	1.10	0.66	1.76	1.8
Stabilization Time, min	5	7.5	5	5.33	5	6.33	5	
Collection Time, min	15	15	10	10	15	15	15	

Table C.5
JOHN DEERE 6068H PROTOTYPE ENGINE 8-MODE STEADY-STATE #3

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	8/9	1991						
Speed, rpm	2200	2200	2200	2200	1300	1300	1300	820
Torque, Ft-lb	364.0	276.0	182.0	36.6	465.0	351.0	234.0	13.0
Power, Hp	151.6	114.3	76.3	14.4	115.7	83.1	56.2	2.9
Water In, deg F	149.2	148.9	148.9	148.6	149.2	148.6	148.6	147.0
Water Out, deg F	157.9	156.6	155.3	152.7	161.0	158.4	155.8	149.7
Oil, deg F	194.1	191.9	190.2	183.0	181.5	185.0	176.7	163.2
Inlet Air, deg F	74.6	74.7	73.2	73.9	74.1	74.3	73.6	75.3
Fuel, deg F	90.6	96.0	87.1	95.7	86.1	95.0	96.0	95.4
Fuel Return, deg F	147.5	152.7	144.0	150.1	141.4	150.5	150.5	147.5
Exhaust, deg F	671.3	602.3	511.6	320.9	754.3	649.2	516.4	238.6
Intercooler In, deg F	264.7	224.2	185.0	144.9	201.5	161.4	138.8	147.6
Intercooler Out, deg F	132.7	120.9	110.9	103.5	107.8	103.9	102.2	150.1
Inlet Restriction in H2O	12.2	9.4	6.8	4.6	2.85	2.1	1.75	0.65
Exhaust Restriction in Hg	2.15	1.65	1.2	0.75	0.5	0.35	0.30	0.1
Fuel Flow, gal/hour	7.8	6.0	4.5	1.8	5.4	3.9	3.0	0.3
Boost Pressure, psi	12.5	8.75	5.5	1.85	7.25	4.25	2.25	0.0
Sample Zone Temp, deg F	211	177.2	149.6	105.5	136.6	125.5	107.7	80.3
Filter Face Temp, deg F	124.8	117.6	115.8	101.2	112.7	110.8	102.2	87.1
Total Tunnel Flow, ft^3	17370	26570	27240	28010	18200	27590	27950	38160
Exhaust HC, ppm	14.42	16.00	16.32	52.51	5.83	5.07	7.90	10.07
Exhaust NO_x, ppm	127.0	96.69	67.30	21.50	137.2	116.5	83.73	13.06
Exhaust CO_2, %	1.392	1.103	0.774	0.312	0.999	0.700	0.484	0.000
Exhaust CO, ppm	12.52	15.05	26.23	95.89	55.78	9.43	7.59	0.00
Background HC, ppm	4.97	4.52	4.38	5.42	3.26	4.30	3.93	3.78
Background NO_x, ppm	1.80	1.03	0.51	2.06	0.26	0.26	0.26	0.51
Background CO_2, %	0.041	0.035	0.033	0.028	0.033	0.033	0.032	0.036
Background CO, ppm	3.09	2.20	2.42	2.64	2.42	2.42	1.98	24.68
Stabilization Time, min	20	5	5.5	6	6.5	5	5	5
Collection Time, min	10	15	15	15	10	15	15	20

Table C.6
JOHN DEERE 6068H PROTOTYPE ENGINE 8-MODE STEADY-STATE #4

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	8/12	1991						
Speed, rpm	2200	2200	2200	2200	1300	1300	1300	820
Torque, Ft-lb	373	280.0	186.5	37.3	468.0	351.0	234.0	0
Power, Hp	150.6	114.0	78.7	12.6	115.4	86.0	57.0	3.0
Water In, deg F	149.6	149.2	149.6	149.2	148.9	148.6	148.9	148.6
Water Out, deg F	158.8	156.6	155.8	152.3	161.4	158.8	156.2	150.5
Oil, deg F	194.6	191.1	188.0	181.5	184.1	183.7	175.8	153.6
Inlet Air, deg F	75.0	75.3	75.3	74.3	75.3	75.7	75.0	73.2
Fuel, deg F	94.0	93.0	88.2	88.2	86.5	95.4	94.1	95.7
Fuel Return, deg F	151.0	151.0	143.6	144.0	142.3	151.0	150.1	147.5
Exhaust, deg F	667.8	594.9	510.4	314.2	772.1	647.9	499.5	201.8
Intercooler In, deg F	263.4	249.2	186.9	142.7	200.7	164.0	139.2	109.6
Intercooler Out, deg F	131.8	126.6	110.9	102.2	107.4	103.0	100.8	100.4
Inlet Restriction in H2O	12.2	9.2	7.0	4.7	2.5	2.1	1.8	0.5
Exhaust Restriction in Hg	2.2	1.75	1.2	0.65	0.4	0.35	2.5	0.2
Fuel Flow, gal/hour	7.8	6.0	4.5	1.5	5.7	3.9	3.0	0.3
Boost Pressure, psi	12.5	9.0	5.9	2.0	5.5	4.5	2.5	0
Sample Zone Temp, deg F	210.8	175.2	143.6	101.9	143.9	125.8	108.0	77.1
Filter Face Temp, deg F	139.0	126.2	116.9	100.2	119.7	111.8	102.9	84.7
Exhaust HC, ppm	18.63	19.53	19.98	57.36	4.98	5.87	8.45	11.22
Exhaust NO_x, ppm	120.4	95.68	68.06	23.00	140.7	118.9	83.23	13.57
Exhaust CO_2, %	1.442	1.109	0.787	0.315	1.001	0.736	0.497	0.072
Exhaust CO, ppm	7.582	13.50	23.04	87.27	28.39	7.884	7.731	29.71
Background HC, ppm	4.23	4.60	5.04	4.45	4.67	4.90	4.52	4.00
Background NO_x, ppm	0.49	0.77	0.77	0.51	0.26	0.26	0.26	0.26
Background CO_2, %	0.037	0.037	0.037	0.033	0.033	0.032	0.032	0.030
Background CO, ppm	4.41	4.19	4.19	3.97	3.75	3.53	3.53	3.39
Stabilization Time, min	20	10	8.3	8.5	7.9	8.5	8.0	8.0
Collection Time, min	10	15	15	15	10	15	15	10

Table C.7
FORD NEW HOLLAND PRODUCTION ENGINE 8-MODE STEADY-STATE #1

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	11/6	1991						
Speed, rpm	2100	2100	2100	2100	1260	1260	1260	750
Torque, Ft-lb	328	246	164	32.8	383	287	192	0
Power, Hp	130.3	100.4	60.7	6.5	90.7	65.9	46.1	0
Water Out, deg F	163.5	161.5	159.9	158.2	162.9	160.9	159.2	155.2
Oil, deg F	207.8	206.4	197.1	184.2	188.5	186.1	176.2	136.6
Inlet Air, deg F	83.4	82.7	80.6	81.3	81.0	80.3	79.6	81.0
Fuel Return, deg F	101.9	103.2	104.3	103.9	104.3	104.6	104.6	104.3
Exhaust, deg F	1143	907.8	652.2	411.1	1045	768.3	585.0	232.9
Inlet Restriction in H2O		10.9	13.3	13.3	4.9	5.0	5.1	1.9
Exhaust Restriction in Hg	4.0	3.2	2.8	2.1	1.8	1.3	0.8	0.1
Fuel Flow, gal/hour	7.2	5.7	3.6	1.8	4.8	3.3	2.2	0.3
Sample Zone Temp, deg F	181.5	157.2	132.9	94.7	123.4	117.3	104.3	80.6
Filter Face Temp, deg F	128.6	123.8	118.0	102.2	107.3	107.7	100.8	88.9
Total Tunnel Flow, ft^3	17680	27010	27510	28070	18410	27860	28140	38250
Exhaust HC, ppm	8.24	34.19	52.48	133.85	11.08	23.48	28.21	20.00
Exhaust NO_x, ppm	151.9	106.8	59.80	8.99	112.5	107.8	71.28	4.37
Exhaust CO_2, %	1.091	0.837	0.536	0.225	0.786	0.551	0.374	0.043
Exhaust CO, ppm	358.9	103.8	53.03	76.41	337.0	37.11	14.34	11.37
Background HC, ppm	3.30	3.30	3.30	4.20	4.20	4.20	3.60	3.60
Background NO_x, ppm	1.03	1.03	1.03	1.03	1.03	1.03	0.51	0.51
Background CO_2, %	0.037	0.037	0.037	0.033	0.033	0.033	0.026	0.026
Background CO, ppm	5.67	5.67	5.67	7.56	7.56	7.56	5.67	5.67
Stabilization Time, min	5	5	5	5	5	5	5	5
Collection Time, min	10	15	15	15	10	15	15	20

Table C.8
FORD NEW HOLLAND PRODUCTION ENGINE 8-MODE STEADY-STATE #2

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	11/8	1991						
Speed, rpm	2100	2100	2100	2100	1260	1260	1260	750
Torque, Ft-lb	328	246	164	32.8	384	288	192	0
Power, Hp	129.9	96.8	66.3	10.3	91.1	63.2	39.3	0
Water Out, deg F	163.9	161.9	160.9	158.5	163.5	161.2	159.2	155.6
Oil, deg F	208.4	206.4	196.8	187.8	188.5	188.8	173.8	137.3
Inlet Air, deg F	81.7	80.0	81.3	82.3	81.3	80.6	79.6	81.0
Fuel Return, deg F	99.8	101.0	101.0	102.6	102.0	103.2	103.6	103.0
Exhaust, deg F	1150	894.7	706.0	457.0	1055	788.4	543.8	260.8
Inlet Restriction in H2O	12.9	12.8	13.1	13.4	4.9	5.1	5.2	2.1
Exhaust Restriction in Hg	4.6	3.85	3.4	2.3	1.9	1.3	0.9	0.1
Fuel Flow, gal/hour	7.1	5.0	3.7	1.6	4.8	3.2	2.0	0.2
Sample Zone Temp, deg F	195.1	169.5	143.9	114.2	125.2	121.4	106.3	82.0
Filter Face Temp, deg F	123.8	123.8	119.7	106.0	107.3	107.3	99.8	87.8
Total Tunnel Flow, ft^3	8880	18050	18390	18800	9310	28110	28440	38360
Exhaust HC, ppm	7.32	34.81	46.61	98.23	11.93	26.90	27.00	19.40
Exhaust NO_x, ppm	162.7	115.7	78.26	14.86	115.5	109.3	66.29	4.88
Exhaust CO_2, %	1.023	0.904	0.653	0.282	0.808	0.551	0.370	0.045
Exhaust CO, ppm	304.3	86.40	43.00	68.84	285.6	24.68	13.23	10.40
Background HC, ppm	3.30	3.30	6.66	3.30	3.30	3.30	3.45	3.45
Background NO_x, ppm	0.51	0.51	0.51	0.51	0.51	0.51	1.03	1.03
Background CO_2, %	0.037	0.037	0.037	0.035	0.035	0.035	0.026	0.026
Background CO, ppm	11.34	11.34	11.34	2.84	2.84	2.84	0.00	0.00
Stabilization Time, min	NA	5	5	5	5	5	5	5
Collection Time, min	5	10	10	10	5	15	15	20

Table C.9
FORD NEW HOLLAND PRODUCTION ENGINE 8-MODE STEADY-STATE #3

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	11/18	1991						
Speed, rpm	2100	2100	2100	2100	1260	1260	1260	750
Torque, Ft-lb	328	246	164	32.8	383	287	192	0
Power, Hp	131.2	91.17	64.78	43.75	91.89	68.6	47.9	
Water Out, deg F	163.2	161.5	159.9	157.6	163.5	160.2	158.9	154.9
Oil, deg F	214.4	207.4	197.5	188.8	185.8	187.8	175.5	133.3
Inlet Air, deg F	75.3	75.3	76.0	76.4	76.8	75.7	76.0	76.0
Fuel Return, deg F	99.1	99.5	103.6	103.2	103.2	103.6	104.3	103.2
Exhaust, deg F	1158	893.1	704.3	454.4	1034	863.1	569.9	178.3
Inlet Restriction in H2O	12.3	12.8	13.1	13.2	4.75	4.8	5.0	1.9
Exhaust Restriction in Hg	4.7	3.9	3.3	2.5	1.9	1.65	1.0	0.1
Fuel Flow, gal/hour	9.3	4.8	3.7	1.7	4.7	3.9	2.1	0.2
Sample Zone Temp, deg F	198.8	172.8	140.9	113.5	125.8	121.1	105.8	78.5
Filter Face Temp, deg F	141.3	111.5	105.3	105.3	109.1	110.1	100.8	86.8
Total Tunnel Flow, ft^3	8890	8930	18110	18500	9180	27550	27990	38000
Exhaust HC, ppm	6.34	33.35	50.45	99.28	13.29	26.03	27.46	23.46
Exhaust NO_x, ppm	171.6	110.3	76.27	16.38	114.5	121.4	66.54	3.08
Exhaust CO_2, %	1.014	0.853	0.638	0.295	0.812	0.652	0.368	0.041
Exhaust CO, ppm	282.5	65.37	43.53	74.67	311.1	35.66	15.83	17.05
Background HC, ppm	4.20	4.20	4.20	3.45	3.45	3.45	3.60	3.60
Background NO_x, ppm	0.26	0.26	0.26	0.00	0.00	0.00	0.00	0.00
Background CO_2, %	0.039	0.039	0.039	0.031	0.031	0.031	0.037	0.037
Background CO, ppm	1.25	1.25	1.25	0.63	0.63	0.63	1.88	1.88
Stabilization Time, min	5	5	5	5	5	5	5	5
Collection Time, min	5	5	10	10	5	15	15	20

D. Reordered Steady-State Modal Data from John Deere

Table D.1
JOHN DEERE 4045T STEADY-STATE #1--EPA MODE ORDER

Run Number	1	2	3	4	5	6	7	8
Date	8/21	1991						
Speed, rpm	1500	1500	1500	1800	1800	1800	1800	800
Torque, Ft-lb	173.7	258.9	340.0	328.2	243.4	162.5	33.7	5.1
Throttle, %	50	75	100	100	75	50	10	0.0
Power, HP	49.6	73.9	97.1	110.7	83.4	56.7	11.5	0.6
HC, g/hr	12.2	15.5	7.9	11.7	16	13.1	29.3	6.3
HC, g/Bhp-hr	0.25	0.21	0.08	0.11	0.19	0.23	2.54	8.18
HC, cwg/hr	1.22	1.55	0.79	1.755	2.4	1.965	2.93	0.945
CO, g/hr	53.2	88.4	573.2	415.5	125.2	75.1	144.7	32.9
CO, g/Bhp-hr	1.07	1.2	5.9	3.75	1.5	1.35	12.52	42.45
CO, cwg/hr	5.32	8.84	57.32	62.325	18.78	11.265	14.47	4.935
NO_x, g/hr	376.7	787.9	1020.4	1153	710	340.8	72.4	33.5
NO_x, g/Bhp-hr	7.6	10.66	10.51	10.41	8.51	6.12	6.27	43.27
NO_x, cwg/hr	37.67	78.79	102.4	172.95	106.5	51.12	7.24	5.025
Filter Mass, mg	1.81	1.25	1.54	0.9	0.97	1.3	0.7	0.58
Filter Temp, Deg C	54.6	57.5	54.2	50.8	53.1	52.4	49	
CO_2, %	7.31	10.17	12.33	11.05	9.0	6.87	2.82	1.51
Dry A/F, Carbon Bal.	29.83	21.71	17.82	19.91	24.4	31.67	73.95	137.72
Dry Air/Fuel, meas.	29.22	21.54	17.96	19.7	23.69	31.58	71.53	129.4
Fuel Rate, lbm/hr	17.7	25.9	35.4	40.3	29.6	20.3	7.8	1.8
Weight %	0.1	0.1	0.1	0.15	0.15	0.15	0.1	0.15
Weighted Hp	4.96	7.39	9.71	15.61	12.51	8.35	1.15	0.12

Table D.2
JOHN DEERE 4045T STEADY-STATE #2--EPA MODE ORDER

Run Number	1	2	3	4	5	6	7	8
Date	8/22	1991						
Speed, rpm	1500	1500	1500	1800	1800	1800	1800	800
Torque, Ft-lb	172.5	258.7	343.2	326.5	242.8	165.0	33.4	8.1
Throttle, %	50	75	100	100	75	50	10	0.0
Power, HP	49.2	73.8	97.9	111.9	83.2	56.5	11.4	1.2
HC, g/hr	11.3	15.8	8.2	11.6	15.6	13.5	23.5	5.8
HC, g/Bhp-hr	0.23	0.21	0.08	0.1	0.19	0.24	2.05	4.7
HC, cwg/hr	1.13	1.58	0.82	1.74	2.34	2.03	2.35	0.87
CO, g/hr	53.2	81.1	561.5	379.8	107.2	74.1	133.3	35.4
CO, g/Bhp-hr	1.06	1.1	5.73	3.39	1.29	1.31	11.64	28.72
CO, cwg/hr	5.32	8.11	58.15	58.97	16.08	11.12	13.33	5.31
NO_x, g/hr	379.7	769.7	1052.9	1181.6	709.6	351.2	73.0	35.2
NO_x, g/Bhp-hr	7.71	10.42	10.75	10.56	8.53	6.21	6.37	28.54
NO_x, cwg/hr	37.97	76.97	106.29	177.24	106.44	52.68	7.30	5.23
Filter Mass, mg	1.45	1.39	1.42	0.78	1.56	1.28	0.57	0.57
Filter Temp, Deg C	52.4	58.4	57.6	59.4	57.8	54.6	50	46
CO_2, %	7.35	10.05	12.33	11.06	9.07	6.74	2.83	1.53
Dry A/F, Carbon Bal.	29.67	21.95	17.82	19.92	24.2	32.26	73.79	136.8
Dry Air/Fuel, meas.	29.37	21.85	17.81	19.65	24.1	31.89	74.51	124.1
Fuel Rate, lbm/hr	17.5	25.7	35.9	40.6	29.5	20.9	7.6	1.9
Weight %	0.1	0.1	0.1	0.15	0.15	0.15	0.1	0.15
Weighted Hp	4.92	7.38	8.79	16.78	12.46	8.48	1.14	0.18

Table D.3
JOHN DEERE 4045T STEADY-STATE #3--ISO MODE ORDER

Run Number	1	2	3	4	5	6	7	8
Date	8/21	1991						
Speed, rpm	1800	1800	1800	1800	1500	1500	1500	800
Torque, Ft-lb	322.3	242.7	162.1	33.6	344.3	257.9	172.3	7.6
Throttle, %	100	75	50	10	100	75	50	0.0
Power, HP	110.7	83.4	56.7	11.5	96.5	73.8	49.3	1.2
HC, g/hr	11.7	18	13.1	29.3	9.6	16.3	11.6	6.2
HC, g/Bhp-hr	0.11	0.19	0.23	2.54	0.1	0.22	0.24	5.35
HC, cwg/hr	1.76	2.40	1.97	2.93	0.98	1.63	1.18	0.93
CO, g/hr	416.5	125.2	75.1	144.7	565.7	84.4	51.4	31.8
CO, g/Bhp-hr	3.75	1.5	1.36	12.52	5.74	1.14	1.04	27.55
CO, cwg/hr	62.33	18.78	11.27	14.47	58.57	8.44	5.14	4.77
NO_x, g/hr	1153	710	340.8	72.4	1015.7	761.7	3.67	36.7
NO_x, g/Bhp-hr	10.41	8.51	6.12	8.27	10.31	10.31	7.44	31.77
NO_x, cwg/hr	172.9	106.50	51.12	7.24	101.57	78.17	36.70	5.51
Filter Mass, mg	0.9	0.97	1.3	0.7	1.58	1.26	1.4	0.3
Filter Temp, Deg C	50.8	53.2	52.5	48.8	58.6	58.4	55.0	48.5
CO_2, %	11.05	9.0	6.87	2.82	12.42	10.17	7.37	1.62
Dry A/F, Carbon Bal.	19.91	24.4	31.67	73.96	17.71	21.71	29.61	136.5
Dry Air/Fuel, meas.	19.73	23.59	31.58	71.53	17.49	21.37	28.93	127.4
Fuel Rate, lbm/hr	40.3	29.6	20.3	7.8	36.3	25.9	17.6	1.9
Weight %	0.15	0.15	0.15	0.1	0.1	0.1	0.1	0.15
Weighted Hp	16.16	12.51	8.35	1.15	9.85	7.38	4.93	0.17

Table D.4
JOHN DEERE 4045T STEADY-STATE #4--ISO MODE ORDER

Run Number	1	2	3	4	5	6	7	8
Date	8/22	1991						
Speed, rpm	1800	1800	1800	1800	1500	1500	1500	790
Torque, Ft-lb	326.5	242.8	185.0	33.4	345.8	258.8	173.5	11.2
Throttle, %	100	75	50	10	100	75	50	0.0
Power, HP	111.9	83.2	58.5	11.4	98.6	73.6	49.5	1.7
HC, g/hr	11.8	15.8	13.5	23.5	10	14.4	10.4	5.1
HC, g/Bhp-hr	0.1	0.19	0.24	2.05	0.1	0.2	0.21	3.02
HC, cwg/hr	1.74	2.34	2.03	2.35	1.00	1.44	1.04	0.77
CO, g/hr	379.8	107.1	74.1	133.2	552.6	80.6	53.0	31.0
CO, g/Bhp-hr	3.39	1.29	1.31	11.64	5.6	1.09	1.07	18.31
CO, cwg/hr	56.97	16.07	11.12	13.32	55.26	8.06	5.30	4.65
NO_x, g/hr	1182	709.6	351.2	73	1067.8	771.5	368.7	38.1
NO_x, g/Bhp-hr	10.56	8.53	6.21	8.37	10.82	10.44	7.44	22.53
NO_x, cwg/hr	177.2	106.44	52.86	7.30	106.78	77.15	36.87	5.72
Filter Mass, mg	0.78	1.56	1.28	0.57	1.67	1.26	1.41	0.38
Filter Temp, Deg C	57.4	58.0	54.8	50.0	58.8	59.4	52.0	43.5
CO_2, %	11.05	9.07	6.74	2.83	12.4	10.07	7.31	1.63
Dry A/F, Carbon Bal.	19.91	24.19	32.25	73.76	17.72	21.9	29.8	128.2
Dry Air/Fuel, meas.	19.63	24.08	31.87	74.49	17.57	22.31	30.03	125.1
Fuel Rate, lbm/hr	40.8	29.5	20.9	7.6	35.4	25.3	17.3	1.9
Weight %	0.15	0.15	0.15	0.1	0.1	0.1	0.1	0.15
Weighted Hp	16.78	12.48	8.48	1.14	9.86	7.38	4.95	0.26

Table D.5
JOHN DEERE DATA ON REORDERED MODES FOR A HEAVY-DUTY DIESEL ENGINE

Modal Order	EPA (JBBM02)	EPA (JBBM04)	ISO (JBBM03)	ISO (JBBM05)
HC, g/Bhp-hr	0.223	0.210	0.225	0.207
CO, g/Bhp-hr	3.015	2.818	2.962	2.784
NO_x, g/Bhp-hr	9.235	9.305	9.150	9.297

E. Fuel Specifications

Laboratory Report

PHILLIPS 66 COMPANY
A SUBSIDIARY OF PHILLIPS PETROLEUM COMPANY

SPECIALTY CHEMICALS
P.O. BOX 968
BORGER, TX 79008-0968

DATE OF SHIPMENT
06-14-91

CUSTOMER ORDER NO.
5700-09733

INV./REQN. NO.
043398

TRAILER NO.
452

CUSTOM D-2 DIESEL FUEL
LOT R-166

TESTS	RESULTS	SPECIFICATIONS	METHOD
API Gravity	34.8	33-37	ASTM D-1298
Corrosion, 50C, 3 hrs	1A	Report	ASTM D-130
Sulfur wt%	0.2429	0.20-0.50	ASTM D-4294
Flash Point °F, PM	180	130 Min.	ASTM D-93
Pour Point °F	-45	Report	ASTM D-2500
Cloud Point °F	+4	Report	ASTM D-2500
Viscosity,cs 40c	2.6	2.0-3.2	ASTM D-445
Sulfur, wt%	0.26	0.20-0.50	ASTM D-3120
Carbon, wt%	86.4	Report	
Hydrogen, wt%	11.2	Report	
Net Heat of Combustion	18,094	Report	ASTM D-3338
Particulate Matter(mg/l)	8.5	15 Max	ASTM D-2276
Cetane Index	46.5	43-47	ASTM D-976
Cetane Number	46.0	42-50	ASTM D-613
DISTILLATION, °F			ASTM D-86
IBP	364	340-400	
5%	424		
10%	441	400-460	
15%	453		
20%	462		
30%	479		
40%	495		
50%	509	470-540	
60%	524		
70%	538		
80%	556		
90%	580	550-610	
95%	600		
EP	622	580-660	
Loss	0.0		
Residue	2.3		
HYDROCARBON TYPE, VOL%			ASTM D-1319
Aromatics	36.4	27 min.	
Olefins	2.1		
Saturates	61.5		
	100.0		

VRK/LK:laf
06/14/1991

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