

TECHNICAL REPORT

HEAVY-DUTY ENGINE TESTING REPORT
NON-ROAD ENGINE CONFIGURATIONS
INJECTION TIMING EFFECTS
TEST RESULTS - 1992

by

MARK DOORLAG
Technology Evaluation and Testing Support Branch

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Technology Evaluation and Testing Support Branch
Regulation Development and Support Division
Office of Mobile Sources
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1. Executive Summary

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 process, EPA initiated an emission testing program to collect data on the class of engines for which the regulations were being developed. The program also investigated likely control strategies that would be employed as a result of the regulations under consideration and the impact of these strategies on emissions. Of particular interest was the ability of injection timing retardation to lower NO_x emission levels and, in turn, its effect on the other regulated emissions levels. Secondly, the program studied the relationship between On-Highway HD-FTP and 8-mode steady-state emission data on current and potential future non-road engines.

This report contains emission test results from the following five non-road heavy-duty diesel engine configurations:

Table 1.1
Five Non-Road Heavy-Duty Diesel Engine Configurations

	Characteristic					
	Manufact.	Application	Model Year	HP	Injectors	Injection Timing
1	John Deere	Log-Skidder	1990	140	Product. ¹	Product. ¹
2	John Deere	Log-Skidder	1990	140	Product. ¹	Retarded
3	John Deere	Log-Skidder	1990	140	Modified	Retarded
4	Ford New Holland	Ag. Tractor	1991	130	Product. ¹	Product. ¹
5	Ford New Holland	Ag. Tractor	1991	130	Product. ¹	Retarded

¹Product. = Production configuration

Emission testing included operation over the EPA Heavy-Duty On-Highway Federal Test Procedure (HD-FTP) and 8-mode steady-state duty cycles. Each engine configuration 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 1.2 and 1.3.

Table 1.2
Emissions Summary for John Deere 6068T Engine Configurations

John Deere 6068T Non-Road Engine
Production Injection Timing, Production Injectors

	HC	CO	NO _x	PM
	g/bhp-hr (g/kW-hr)			
HD-FTP, Transient	0.858 (1.151)	3.606 (4.836)	10.808 (14.494)	0.405 (0.543)
8-Mode, Steady-State	0.427 (0.573)	3.144 (4.216)	11.758 (15.767)	0.422 (0.566)

John Deere 6068T Non-Road Engine
Retarded Injection Timing, Production Injectors

	HC	CO	NO _x	PM
	g/bhp-hr (g/kW-hr)			
HD-FTP, Transient	1.580 (2.119)	5.433 (7.286)	5.650 (7.577)	0.992 (1.330)
8-Mode, Steady-State	0.933 (1.251)	4.770 (6.397)	6.340 (8.502)	1.089 (1.460)

John Deere 6068T Non-Road Engine
Retarded Injection Timing, Modified Injectors

	HC	CO	NO _x	PM
	g/bhp-hr (g/kW-hr)			
HD-FTP, Transient	0.839 (1.125)	4.262 (5.715)	6.038 (8.097)	0.810 (1.086)
8-Mode, Steady-State	0.774 (1.038)	3.564 (4.779)	7.327 (9.826)	0.866 (1.161)

Table 1.3
Emissions Summary for Ford New Holland Engine Configurations

Ford New Holland Non-Road Engine, Production Injection Timing

	HC	CO	NO _x	PM
	g/bhp-hr (g/kW-hr)			
HD-FTP, Transient	2.116 (2.838)	5.288 (7.091)	10.590 (14.201)	0.902 (1.210)
8-Mode, Steady-State	0.703 (0.943)	5.575 (7.476)	9.272 (12.434)	0.963 (1.291)

Ford New Holland Non-Road Engine, Retarded Injection Timing

	HC	CO	NO _x	PM
	g/bhp-hr (g/kW-hr)			
HD-FTP, Transient	3.639 (4.880)	5.902 ¹ (7.915) ¹	7.055 (9.461)	1.262 (1.692)
8-Mode, Steady-State	1.397 (1.873)	4.767 (6.393)	5.895 (7.905)	1.310 (1.757)

¹This value incorporates data which was measured via continuous integration rather than a bag sample, which was the method used for all the other HD-FTP CO values reported. The author feels that this factor has an insignificant impact on the results.

For the John Deere and Ford New Holland engine, injection timing retardation significantly reduced the NO_x emission levels while increasing the other pollutant (HC, CO, and PM) emission levels over both the 8-mode steady-state (with the exception of CO for the Ford New Holland engine) and the HD-FTP test.

Finally, in comparison to the John Deere engine, retarded configuration utilizing production injectors, the "modified" injector configuration caused reductions in HC, CO, and PM emission levels, over both the 8-mode steady-state and HD-FTP test, while NO_x slightly increased. These "modified" injectors in the John Deere engine were designed to provide better targeting of the fuel spray plume at retarded injection timings.

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 process, EPA initiated an emission testing program to collect data on the class of engines for which the regulations were being developed. The program also investigated likely control strategies that would be employed as a result of the regulations under consideration and the impact of these strategies on emissions. Of particular interest was the ability of injection timing retardation to lower NO_x emission levels and, in turn, its effect on the other regulated emissions levels. Secondly, the program studied the relationship between On-Highway HD-FTP and 8-mode steady-state emission data on current and potential future non-road engines.

Test results for five engine configurations (three John Deere engine configurations and two Ford New Holland engine configurations) are presented in this report. The John Deere engine configurations consisted of a production non-road engine, the same engine with retarded injection timing, and the same engine with modified fuel injectors (while maintaining the aforementioned retarded injection timing). The Ford New Holland engine configurations consisted of a production non-road engine and the same engine with retarded injection timing.

3. Engines

Table 3.1 summarizes the specifications for the two engines (five engine configurations) which were used in this program. The 1990 model year John Deere 6068T was a turbocharged, in-line 6-cylinder, 6.8 L displacement heavy-duty diesel engine. Rated and peak torque speed for this direct injection engine were 2200 and 1300 RPM, respectively, with a rated horsepower of 139 hp (103.7 kW).

The 1991 model year Ford New Holland heavy-duty diesel engine was an in-line 6-cylinder, 7.5 L displacement, with no turbocharging. Rated speed and peak torque speeds for this direct injection engine were 2100 and 1200 RPM respectively, with a rated horsepower of 127 hp (94.7 kW).

Table 3.1
Engine Specifications

Manufacturer	John Deere			Ford New Holland
Model	6068T			----
Use	Log-Skidder			Ag. Tractor
Engine Serial Number	JDPRODT6068T35JL			358/117-91-89V
Model Year	1990			1991
Rated Power (bhp)	139			127
Rated Speed (rpm)	2200			2100
Peak Torque (ft-lb)	467			383
Peak Torque Speed (rpm)	1300			1200
Injection Timing (°BTDC)	15 ¹	~ 7 ²		8 ¹ ~ 4 ²
Injectors	Product. ³	Product. ³	Modified	Product. ³
Cylinders	6			6
Cylinder Configuration	in-line			in-line
Bore x Stroke (in)	4.19 x 5.0			4.4 x 5.0
Displacement (in ³ - liter)	414 - 6.8			456 - 7.5
Aspiration	turbo			natural
Aftercooling	none			none

¹Production injection timing.

²Retarded injection timing.

³Production.

The modified injectors used with the John Deere 6068T engine were actually experimental injectors provided by John Deere. They were designed to provide better targeting of the fuel spray plume at retarded injection timings.

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 Appendix A. 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 TEST	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 86.1313-90(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 Performance

Each of the engines were set up in the EPA National Vehicle and Fuel Emissions Laboratory (NVFEL) 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 $\pm 2^{\circ}$ 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 HD-FTP 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 HD-FTP 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 on-highway heavy-duty diesel emissions measurement.

5.3 Steady State (8-Mode) Testing

Two 8-mode steady state emission tests were performed on each of the three John Deere 6068T engine configurations and on each of the two Ford New Holland engine configurations. The ISO 8178 8-mode test procedure (which is very similar to the proposed non-road test procedure found in CFR 40 Part 89 - Control of Emission from New and In-Use Nonroad Engines for New Nonroad Compression-Ignition Engines at or above 50 Horsepower, Subpart D and E - Emission Test Equipment Equipment Provisions and Procedures) was used along with particulate matter procedures described in Appendix B. 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 and one particulate filter for each mode.

5.4 Federal On-Highway Smoke Testing

A modified version of the Federal on-highway smoke test was performed on each of the three John Deere 6068T engine configurations and on each of the two Ford New Holland engine configurations. These tests were not intended to yield Federal Smoke Test Procedure results, but rather were performed in order to observe the directional change in smoke levels due to injection timing. The results are summarized in a memorandum in Appendix C.

6. John Deere 6068T Engine, Production Injection Timing, Production Injectors 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.

6.2 HD-FTP Transient Testing/Results

After the engine was torque mapped, two HD-FTP transient test sequences were run. Each sequence 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 are presented in Table 6.2. The NO_x level of 10.808 g/bhp-hr measured for this engine configuration is higher than the on-highway pre-control standard level of 10.7 g/bhp-hr. However, the measured PM level of 0.405 g/bhp-hr is lower than the on-highway first level of control of 0.6 g/bhp-hr. This is probably due to an advanced engine timing schedule.

6.3 Steady State (8-Mode) Testing/Results

The steady-state test was performed twice on this engine configuration. Average composite HC, CO, NO_x , and PM levels were determined to be 0.427, 3.144, 11.758, and 0.422 g/bhp-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 detailed 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 modal weighting factor used in computing the modal-weighted composite brake specific emissions at the bottom of each table. The other groupings of data include the mass emission rate in grams/hour for each mode, the 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 6.1
John Deere 6068T Engine, Production Injection Timing,
Production Injectors 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

Table 6.2
John Deere 6068T Engine, Production Injection Timing,
Production Injectors HD-FTP Transient Test Results

	HC (g/bhp-hr)	CO (g/bhp-hr)	NO _x (g/bhp-hr)	PM (g/bhp-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 ¹	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 ¹	0.816	3.353	10.989	0.398
Average ²				
	0.858	3.606	10.808	0.405

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

²Average of the 2 composite values.

Table 6.3
John Deere 6068T Engine, Production Injection Timing, Production Injectors
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/bhp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-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/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
	0.346	0.445	2.972	11.728	0.409

Table 6.4
John Deere 6068T Engine, Production Injection Timing, Production Injectors
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/bhp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-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/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
	0.351	0.408	3.316	11.787	0.434

7. John Deere 6068T Engine, Retarded Injection Timing, Production Injectors Testing/Results

7.1 Steady State Performance Evaluation

While the engine remained installed in the test cell, the injection timing was retarded to approximately 7° BTDC from 15° BTDC. The engine was then run at steady state conditions while speeds, torques, and fuel flows were recorded. These values were compared to the engine manufacturer's production engine, production injection timing data (see Table 7.1) and notable differences in the torque measurements were discovered. These differences could be adequately explained by the retarded injection timing and thus EPA concluded that the engine was operating properly.

7.2 HD-FTP Transient Testing/Results

After the engine was torque mapped, two HD-FTP transient test sequences were run. Average composite HC, CO, NO_x, and PM levels were determined to be 1.580, 5.433, 5.650, and 0.992 g/bhp-hr respectively. NO_x was reduced by 47.7% while HC, CO, and PM increased due to the injection timing retardation. The HD-FTP test results for the retarded John Deere engine configuration are presented in Table 7.2.

7.3 Steady State (8-Mode) Testing/Results

The steady-state test was performed twice on this engine configuration. Average composite HC, CO, NO_x, and PM levels were determined to be 0.933, 4.770, 6.340, and 1.089 g/bhp-hr respectively. Due to injection timing retardation, the HD-FTP transient test showed NO_x and PM changes of -47.7% and 144.9% respectively, while the steady-state test showed very similar changes of -46.1% and 158.1% for NO_x and PM. The detailed 8-mode steady-state test results are presented in Tables 7.3 and 7.4.

Table 7.1
John Deere 6068T Engine, Retarded Injection Timing,
Production Injectors Steady State Performance Data

LAB	TORQUE, FT-LB		FUEL FLOW, GAL/HR	
	1300 RPM	2200 RPM	1300 RPM	2200 RPM
JOHN DEERE VALUES ¹	467.0	332.0	5.7	7.2
EPA VALUES	476.0	320.0	5.7	7.2

¹Engine manufacturer's production engine, production injection timing data.

Table 7.2
John Deere 6068T Engine, Retarded Injection Timing,
Production Injectors HD-FTP Transient Test Results

	HC (g/bhp-hr)	CO (g/bhp-hr)	NO _x (g/bhp-hr)	PM (g/bhp-hr)
First Sequence				
Cold Start	2.204	6.104	5.694	1.135
Hot Start #1	1.616	5.444	5.634	1.003
Hot Start #2	1.436	4.905	5.506	0.928
Composite ¹	1.701	5.539	5.643	1.022
Second Sequence				
Cold Start	1.871	6.170	5.926	1.048
Hot Start #1	1.390	5.186	5.611	0.948
Hot Start #2	1.357	4.930	5.648	0.937
Composite ¹	1.459	5.326	5.656	0.962
Average²				
	1.580	5.433	5.650	0.992

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

²Average of the 2 composite values.

Table 7.3
John Deere 6068T Engine, Retarded Injection Timing, Production Injectors
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%	2200	320.0	134.0
2	Rated	75	15%	2200	241.0	101.0
3	Rated	50	15%	2200	161.5	67.7
4	Rated	10	10%	2200	37.0	15.5
5	Int	100	10%	1300	476.0	117.8
6	Int	75	10%	1300	356.0	88.1
7	Int	50	10%	1300	260.0	64.4
8	Idle	0	15%	960	5.0	0.9

Mode g/hr results						
Mode	HP	Fuel ¹ lb/hr	HC g/hr	CO g/hr	NO _x g/hr	PM g/hr
1	134.0	50.78	29.26	682.85	799.56	145.85
2	101.0	42.26	27.71	579.61	502.81	132.06
3	67.7	29.54	43.40	255.64	300.36	70.13
4	15.5	16.88	436.66	521.87	97.58	92.34
5	117.8	42.20	18.20	289.99	971.62	97.99
6	88.1	33.76	26.14	60.98	610.25	35.36
7	64.4	21.10	20.78	431.65	442.84	92.89
8	0.9	2.76	25.58	65.84	36.26	4.02

¹Fuel consumption is measured, only idle mode is calculated from exhaust emissions.

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO _x g/lb	PM g/lb
1	134.0	NA	0.58	13.45	15.75	2.87
2	101.0	NA	0.66	13.72	11.90	3.12
3	67.7	NA	1.47	8.65	10.17	2.37
4	15.5	NA	25.87	30.92	5.78	5.47
5	117.8	NA	0.43	6.87	23.02	2.32
6	88.1	NA	0.77	1.81	18.08	1.05
7	64.4	NA	0.99	20.46	20.99	4.40
8	0.9	NA	9.27	23.86	13.14	1.46

Mode g/bhp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
1	134.0	0.379	0.218	5.094	5.965	1.088
2	101.0	0.419	0.274	5.741	4.981	1.308
3	67.7	0.437	0.642	3.779	4.440	1.037
4	15.5	1.089	28.173	33.671	6.296	5.958
5	117.8	0.358	0.155	2.461	8.246	0.832
6	88.1	0.383	0.297	0.692	6.925	0.401
7	64.4	0.328	0.323	6.707	6.881	1.443
8	0.9	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
	0.356	0.932	4.966	6.181	1.142

Table 7.4
John Deere 6068T Engine, Retarded Injection Timing, Production Injectors
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%	2200	320.5	134.3
2	Rated	75	15%	2200	244.0	102.2
3	Rated	50	15%	2200	163.5	68.5
4	Rated	10	10%	2200	32.0	13.4
5	Int	100	10%	1300	475.0	117.6
6	Int	75	10%	1300	352.0	87.1
7	Int	50	10%	1300	243.5	60.3
8	Idle	0	15%	960	0.0	0.0

Mode g/hr results						
Mode	HP	Fuel ¹ lb/hr	HC g/hr	CO g/hr	NO _x g/hr	PM g/hr
1	134.3	50.67	30.80	805.31	863.44	154.52
2	102.2	42.22	26.93	564.26	544.52	132.82
3	68.5	29.54	42.83	258.60	325.12	71.53
4	13.4	14.76	438.38	502.25	87.43	80.56
5	117.6	42.17	17.84	274.79	1010.78	94.22
6	87.1	29.54	24.07	49.64	634.49	33.84
7	60.3	18.99	20.90	29.72	395.20	10.09
8	0.0	2.56	23.36	44.30	35.86	3.64

Fuel consumption is measured, only idle mode is calculated from exhaust emissions.

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO _x g/lb	PM g/lb
1	134.3	NA	0.61	15.89	17.04	3.05
2	102.2	NA	0.64	13.36	12.90	3.15
3	68.5	NA	1.45	8.75	11.01	2.42
4	13.4	NA	29.70	34.03	5.92	5.46
5	117.6	NA	0.42	6.52	23.97	2.23
6	87.1	NA	0.81	1.68	21.48	1.15
7	60.3	NA	1.10	1.56	20.81	0.53
8	0.0	NA	9.13	17.30	14.01	1.42

Mode g/bhp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
1	134.3	0.377	0.229	5.998	6.431	1.151
2	102.2	0.413	0.263	5.521	5.328	1.299
3	68.5	0.431	0.625	3.776	4.747	1.044
4	13.4	1.101	32.704	37.469	6.523	6.010
5	117.6	0.359	0.152	2.337	8.597	0.801
6	87.1	0.339	0.276	0.570	7.282	0.388
7	60.3	0.315	0.347	0.493	6.557	0.167
8	0.0	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
	0.370	0.934	4.573	6.498	1.036

8. John Deere 6068T Engine, Retarded Injection Timing, Modified Injectors Testing/Results

8.1 Steady State Performance Evaluation

While the engine injection timing remained in the retarded condition of approximately 7° BTDC, the production injectors were replaced with "modified" injectors. These "modified" injectors were designed to provide better combustion chamber targeting of the fuel spray plume at retarded injection timings. The engine was then run at steady state conditions while speeds, torques, and fuel flows were recorded. These values were compared to the engine manufacturer's production engine, production injection timing data (see Table 8.1) and a notable difference in the torque measurement at 1300 rpm was discovered. This difference could be attributed to the combination of the retarded injection timing and "modified" injectors and thus the difference was not investigated in this program.

8.2 HD-FTP Transient Testing/Results

After the engine was torque mapped, two HD-FTP transient test sequences were run. Average composite HC, CO, NO_x, and PM levels were determined to be 0.839, 4.262, 6.038, and 0.810 g/bhp-hr respectively. NO_x slightly increased while HC, CO, and PM were reduced in comparison to the retarded configuration using production injectors. The HD-FTP test results for the John Deere engine retarded timing configuration equipped with "modified" injectors are presented in Table 8.2.

8.3 Steady State (8-Mode) Testing/Results

The steady-state test was performed twice on this engine configuration. Average composite HC, CO, NO_x, and PM levels were determined to be 0.774, 3.564, 7.327, and 0.866 g/bhp-hr respectively. In comparison to the retarded engine configuration using production injectors, the "modified" injectors showed NO_x and PM changes of 15.6% and -20.5% respectively, over the steady-state test. Similarly, the HD-FTP transient test showed changes of 6.9% and -18.3% for NO_x and PM, respectively. The detailed 8-mode steady-state test results are presented in Tables 8.3 and 8.4.

Table 8.1
John Deere 6068T Engine, Retarded Injection Timing,
Modified Injectors Steady State Performance Data

LAB	TORQUE, FT-LB		FUEL FLOW, GAL/HR	
	1300 RPM	2200 RPM	1300 RPM	2200 RPM
JOHN DEERE VALUES ¹	467.0	332.0	5.7	7.2
EPA VALUES	485.0	331.5	5.7	7.2

¹Engine manufacturer's production engine, production injection timing data.

Table 8.2
John Deere 6068T Engine, Retarded Injection Timing,
Modified Injectors HD-FTP Transient Test Results

	HC (g/bhp-hr)	CO (g/bhp-hr)	NO _x (g/bhp-hr)	PM (g/bhp-hr)
First Sequence				
Cold Start	1.135	5.085	5.907	0.895
Hot Start #1	0.791	4.116	5.907	0.794
Hot Start #2	0.716	3.961	5.931	0.754
Composite ¹	0.840	4.255	5.907	0.808
Second Sequence				
Cold Start	1.261	5.324	6.446	0.937
Hot Start #1	0.765	4.089	6.121	0.790
Hot Start #2	0.822	4.215	6.185	0.758
Composite ¹	0.837	4.268	6.168	0.811
Average ²				
	0.839	4.262	6.038	0.810

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

²Average of the 2 composite values.

Table 8.3
John Deere 6068T Engine, Retarded Injection Timing, Modified Injectors
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%	2200	331.5	138.9
2	Rated	75	15%	2200	250.2	104.8
3	Rated	50	15%	2200	165.5	69.3
4	Rated	10	10%	2200	37.0	15.5
5	Int	100	10%	1300	485.0	120.0
6	Int	75	10%	1300	364.0	90.1
7	Int	50	10%	1300	245.0	60.6
8	Idle	0	15%	960	3.0	0.5

Mode g/hr results						
Mode	HP	Fuel ¹ lb/hr	HC g/hr	CO g/hr	NO _x g/hr	PM g/hr
1	138.9	50.62	14.33	535.64	990.42	138.54
2	104.8	40.06	12.84	364.06	618.52	116.96
3	69.3	27.39	22.37	176.21	356.90	62.33
4	15.5	12.64	490.19	516.66	99.36	88.57
5	120.0	40.02	9.06	351.76	1114.93	67.88
6	90.1	29.52	13.61	51.75	767.56	21.67
7	60.6	18.97	4.03	6.84	464.72	1.74
8	0.5	2.25	21.62	48.41	27.99	3.31

¹Fuel consumption is measured, only idle mode is calculated from exhaust emissions.

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO _x g/lb	PM g/lb
1	138.9	NA	0.28	10.58	19.57	2.74
2	104.8	NA	0.32	9.09	15.44	2.92
3	69.3	NA	0.82	6.43	13.03	2.28
4	15.5	NA	38.78	40.88	7.86	7.01
5	120.0	NA	0.23	8.79	27.86	1.70
6	90.1	NA	0.46	1.75	26.00	0.73
7	60.6	NA	0.21	0.36	24.50	0.09
8	0.5	NA	9.61	21.51	12.44	1.47

Mode g/bhp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
1	138.9	0.365	0.103	3.857	7.132	0.998
2	104.8	0.382	0.123	3.474	5.902	1.116
3	69.3	0.395	0.323	2.542	5.148	0.899
4	15.5	0.816	31.627	33.335	6.411	5.715
5	120.0	0.333	0.075	2.930	9.287	0.565
6	90.1	0.328	0.151	0.574	8.519	0.240
7	60.6	0.313	0.066	0.113	7.663	6.029
8	0.5	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
	0.303	0.824	3.454	7.186	0.874

Table 8.4
John Deere 6068T Engine, Retarded Injection Timing, Modified Injectors
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%	2200	331.5	138.9
2	Rated	75	15%	2200	251.0	105.1
3	Rated	50	15%	2200	166.0	69.5
4	Rated	10	10%	2200	34.0	14.2
5	Int	100	10%	1300	485.0	120.0
6	Int	75	10%	1300	365.1	90.4
7	Int	50	10%	1300	242.0	59.9
8	Idle	0	15%	960	3.0	0.5

Mode g/hr results						
Mode	HP	Fuel ¹ lb/hr	HC g/hr	CO g/hr	NO _x g/hr	PM g/hr
1	138.9	50.90	15.72	642.32	1045.04	138.23
2	105.1	40.24	13.90	410.23	634.90	117.78
3	69.5	29.61	23.56	186.12	374.03	63.85
4	14.2	14.78	402.19	450.68	100.08	69.35
5	120.0	40.09	11.27	321.13	1157.64	65.86
6	90.4	29.56	13.25	54.33	763.54	20.85
7	59.9	19.00	13.40	27.11	472.92	6.58
8	0.5	2.41	18.08	43.49	45.52	3.39

¹Fuel consumption is measured, only idle mode is calculated from exhaust emissions.

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO _x g/lb	PM g/lb
1	134.3	NA	0.31	12.62	20.53	2.72
2	102.2	NA	0.35	10.19	15.78	2.93
3	68.5	NA	0.80	6.29	12.63	2.16
4	13.4	NA	27.21	30.49	6.77	4.69
5	117.6	NA	0.28	8.01	28.88	1.64
6	87.1	NA	0.45	1.84	25.83	0.71
7	60.3	NA	0.71	1.43	24.89	0.35
8	0.0	NA	7.50	18.05	18.89	1.41

Mode g/bhp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
1	134.3	0.367	0.113	4.626	7.526	0.995
2	102.2	0.383	0.132	3.902	6.039	1.120
3	68.5	0.426	0.339	2.677	5.379	0.918
4	13.4	1.038	28.239	31.644	7.027	4.869
5	117.6	0.334	0.094	2.675	9.643	0.549
6	87.1	0.327	0.147	0.601	8.449	0.231
7	60.3	0.317	0.224	0.453	7.895	0.110
8	0.0	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
	0.348	0.724	3.674	7.468	0.857

9. Ford New Holland Engine, Production Injection Timing Testing/Results

9.1 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 and compared to the engine manufacturer's data (see Table 9.1). The data were found to be similar and thus EPA judged the engine was operating properly.

9.2 HD-FTP Transient Testing/Results

After the engine was torque mapped, two HD-FTP transient test sequences were run. Average composite HC, CO, NO_x, and PM levels were determined to be 2.116, 5.288, 10.590, and 0.902 g/bhp-hr respectively. The NO_x level was near uncontrolled on-road levels, and the PM was relatively high, especially considering the relatively high NO_x level. The HD-FTP test results for the production injection timing Ford New Holland engine configuration are presented in Table 9.2.

9.3 Steady State (8-Mode) Testing/Results

The steady-state test was performed twice on this engine configuration. Average composite HC, CO, NO_x, and PM levels were determined to be 0.703, 5.575, 9.272, and 0.963 g/bhp-hr respectively. The values for CO and PM were similar for both test procedures, but HC and NO_x were 66.8% and 12.4% lower on the 8-mode steady-state test than on the HD-FTP. The detailed 8-mode steady-state test results are presented in Tables 9.3 and 9.4.

Table 9.1
Ford New Holland Engine, Production Injection Timing
Steady State Performance Data

LAB	TORQUE, FT-LB		FUEL FLOW, GAL/HR	
	1260 RPM	2100 RPM	1200 RPM	2100 RPM
FORD N.H. VALUES	383.0	318.0	4.5	7.0
EPA VALUES	380.0	322.0	4.8	7.2

Table 9.2
Ford New Holland Engine, Production Injection Timing
HD-FTP Transient Test Results

	HC (g/bhp-hr)	CO (g/bhp-hr)	NO _x (g/bhp-hr)	PM (g/bhp-hr)
First Sequence				
Cold Start	2.313	5.330	11.047	0.938
Hot Start #1	2.040	4.874	10.927	0.924
Hot Start #2	2.025	4.815	10.104	0.939
Composite ¹	2.080	4.940	10.944	0.926
Second Sequence				
Cold Start	2.537	6.158	11.156	0.985
Hot Start #1	2.086	5.546	10.079	0.859
Hot Start #2	2.097	5.450	9.565	0.971
Composite ¹	2.151	5.635	10.235	0.877
Average²				
	2.116	5.288	10.590	0.902

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

²Average of the 2 composite values.

Table 9.3
Ford New Holland Engine, Production Injection Timing
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	322.0	128.8
2	Rated	75	15%	2100	242.7	97.0
3	Rated	50	15%	2100	164.0	65.6
4	Rated	10	10%	2100	34.5	13.8
5	Int	100	10%	1260	380.0	91.2
6	Int	75	10%	1260	287.9	69.1
7	Int	50	10%	1260	192.4	46.2
8	Idle	0	15%	875	4.5	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	128.8	50.64	8.29	1242.97	1137.29	211.85
2	97.0	33.75	53.62	210.10	892.27	42.79
3	65.6	25.32	75.11	99.23	587.02	33.33
4	13.8	12.67	113.34	129.32	165.95	29.23
5	91.2	33.81	18.78	1070.87	750.66	118.92
6	69.1	23.24	43.35	84.56	699.08	24.12
7	46.2	14.8	50.29	55.16	447.02	27.10
8	0.7	2.25	29.02	49.07	65.71	4.87

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO _x g/lb	PM g/lb
1	128.8	NA	0.16	24.55	22.46	4.18
2	97.0	NA	1.59	6.23	26.44	1.27
3	65.6	NA	2.97	3.92	23.18	1.32
4	13.8	NA	8.95	10.21	13.10	2.31
5	91.2	NA	0.56	31.67	22.20	3.52
6	69.1	NA	1.87	3.64	30.08	1.04
7	46.2	NA	3.40	3.73	30.20	1.83
8	0.7	NA	12.90	21.81	29.21	2.16

Mode g/bhp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
1	128.8	0.393	0.064	9.654	8.833	1.645
2	97.0	0.348	0.552	2.165	9.195	0.441
3	65.6	0.386	1.145	1.513	8.952	0.508
4	13.8	0.918	8.216	9.375	12.030	2.119
5	91.2	0.371	0.206	11.746	8.234	1.304
6	69.1	0.336	0.628	1.224	10.121	0.349
7	46.2	0.321	1.090	1.195	9.684	0.587
8	0.7	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
	0.366	0.721	5.684	9.244	0.970

Table 9.4
Ford New Holland Engine, Production Injection Timing
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	326.0	130.4
2	Rated	75	15%	2100	245.6	98.2
3	Rated	50	15%	2100	163.5	65.4
4	Rated	10	10%	2097	34.0	13.6
5	Int	100	10%	1260	385.5	92.5
6	Int	75	10%	1260	290.5	69.7
7	Int	50	10%	1260	193.5	46.4
8	Idle	0	15%	890	3.0	0.5

Mode g/hr results						
Mode	HP	Fuel lb/hr	HC g/hr	CO g/hr	NO _x g/hr	PM g/hr
1	130.4	50.94	8.10	926.50	1138.54	216.20
2	98.2	36.08	49.03	167.62	875.08	46.50
3	65.4	25.47	72.58	81.82	714.77	31.32
4	13.6	12.74	107.20	130.98	142.26	30.02
5	92.5	33.96	15.67	1549.84	751.48	106.55
6	69.7	23.33	39.42	57.31	686.01	21.46
7	46.4	14.84	48.25	56.60	429.46	24.95
8	0.5	2.12	32.63	46.61	47.66	7.29

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO _x g/lb	PM g/lb
1	130.4	NA	0.16	18.19	22.35	4.24
2	98.2	NA	1.36	4.65	24.25	1.29
3	65.4	NA	2.85	3.21	28.06	1.23
4	13.6	NA	8.41	10.28	11.17	2.36
5	92.5	NA	0.46	45.64	22.13	3.14
6	69.7	NA	1.69	2.46	29.40	0.92
7	46.4	NA	3.25	3.81	28.94	1.68
8	0.5	NA	15.39	21.99	22.48	3.44

Mode g/bhp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
1	130.4	0.391	0.062	7.108	8.734	1.659
2	98.2	0.367	0.499	1.707	8.911	0.474
3	65.4	0.390	1.110	1.251	10.933	0.479
4	13.6	0.938	7.896	9.648	10.479	2.212
5	92.5	0.367	0.169	16.758	8.125	1.152
6	69.7	0.335	0.566	0.822	9.843	0.308
7	46.4	0.320	1.039	1.219	9.251	0.537
8	0.5	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
	0.308	0.684	5.466	9.299	0.956

10. Ford New Holland Engine, Retarded Injection Timing, Testing/Results

10.1 Steady State Performance Evaluation

While the engine remained installed in the test cell, the injection timing was retarded to approximately 4° BTDC from 8° BTDC. The engine was then run at steady state conditions while speeds, torques, and fuel flows were recorded. These values were compared to the engine manufacturer's production engine, production injection timing data (see Table 10.1) and minor differences in the torque and fuel flow measurements were discovered. These differences could be explained by the retarded injection timing and thus EPA concluded that the engine was operating properly.

10.2 HD-FTP Transient Testing/Results

After the engine was torque mapped, two HD-FTP transient test sequences were run. Average composite HC, CO, NO_x, and PM levels were determined to be 3.639, 5.902, 7.055, and 1.262 g/bhp-hr respectively. As with the John Deere engine, NO_x was reduced while HC, CO, and PM increased due to the injection timing retardation. The HD-FTP test results for the Ford New Holland engine retarded configuration are presented in Table 10.2.

10.3 Steady State (8-Mode) Testing/Results

The steady-state test was performed twice with this engine configuration. Composite HC, CO, NO_x, and PM levels were determined to be 1.397, 4.767, 5.895, and 1.310 g/bhp-hr respectively. Through injection timing retardation, the HD-FTP transient test showed NO_x and PM changes of -33.4% and 39.9% respectively, while the steady-state test showed comparable changes of -36.4% and 36.0% for NO_x and PM. These are very similar changes. The detailed 8-mode steady-state test results are presented in Tables 7.3 and 7.4.

Table 10.1
Ford New Holland Engine, Retarded Injection Timing
Steady State Performance Data

LAB	TORQUE, FT-LB		FUEL FLOW, GAL/HR	
	1200 RPM	2100 RPM	1200 RPM	2100 RPM
FORD N.H. VALUES ¹	383.0	318.0	4.5	7.0
EPA VALUES	386.0	328.0	4.8	7.5

¹Engine manufacturer's production engine, production injection timing data.

Table 10.2
Ford New Holland Engine, Retarded Injection Timing
HD-FTP Transient Test Results

	HC (g/bhp-hr)	CO ¹ (g/bhp-hr)	NO _x (g/bhp-hr)	PM (g/bhp-hr)
First Sequence				
Cold Start	4.451	7.024	7.664	1.569
Hot Start #1	3.375	5.524	6.712	1.170
Hot Start #2	3.219	5.305	6.452	1.124
Composite ²	3.531	5.742	6.850	1.228
Second Sequence				
Cold Start	4.934	7.362	7.280	1.709
Hot Start #1	3.545	5.841	7.256	1.225
Hot Start #2	3.315	5.546	6.511	1.171
Composite ²	3.746	6.061	7.259	1.295
Average³				
	3.639	5.902	7.055	1.262

¹CO was measured via continuous integration rather than bag sample, which was the method used for all the other HD-FTP CO values reported. The author feels that this factor has an insignificant impact on the results.

²Composite = 1/7(Cold Start) + 6/7(Hot Start #1)

³Average of the 2 composite values.

Table 10.3
Ford New Holland Engine, Retarded Injection Timing
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	328.0	131.2
2	Rated	75	15%	2100	250.0	100.0
3	Rated	50	15%	2100	164.0	65.6
4	Rated	10	10%	2100	41.0	16.4
5	Int	100	10%	1260	386.0	92.6
6	Int	75	10%	1260	292.0	70.1
7	Int	50	10%	1260	198.0	47.5
8	Idle	0	15%	890	5.5	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	53.11	7.38	715.42	721.20	254.82
2	100.0	36.10	53.99	134.60	584.94	49.69
3	65.6	25.48	83.16	139.13	403.52	20.50
4	16.4	12.74	534.35	356.80	90.35	136.99
5	92.6	33.98	14.90	1007.56	558.05	160.38
6	70.1	23.35	43.31	59.78	452.32	23.28
7	47.5	35.36	55.15	78.98	314.93	17.27
8	0.9	0.14	53.26	73.22	62.96	10.42

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	0.14	13.47	13.58	4.80
2	100.0	NA	1.50	3.73	16.20	1.38
3	65.6	NA	3.26	5.46	15.84	0.80
4	16.4	NA	41.94	28.01	7.09	10.75
5	92.6	NA	0.44	29.65	16.42	4.72
6	70.1	NA	1.85	2.56	19.37	1.00
7	47.5	NA	1.56	2.23	8.91	0.49
8	0.9	NA	380.42	522.99	449.72	74.40

Mode g/bhp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
1	131.2	0.405	0.056	5.455	5.499	1.943
2	100.0	0.361	0.540	1.347	5.852	0.497
3	65.6	0.389	1.268	2.122	6.154	0.313
4	16.4	0.777	32.595	21.764	5.511	8.356
5	92.6	0.367	0.161	10.880	6.026	1.732
6	70.1	0.333	0.618	0.853	6.457	0.332
7	47.5	0.744	1.161	1.663	6.630	0.364
8	0.9	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
	0.320	1.403	4.601	6.055	1.250

Table 10.4
Ford New Holland Engine, Retarded Injection Timing
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	328.5	131.3
2	Rated	75	15%	2100	249.0	99.6
3	Rated	50	15%	2100	165.6	66.2
4	Rated	10	10%	2100	37.6	15.0
5	Int	100	10%	1260	386.0	92.6
6	Int	75	10%	1260	290.2	69.6
7	Int	50	10%	1260	194.0	46.5
8	Idle	0	15%	890	5.0	0.8

Mode g/hr results						
Mode	HP	Fuel lb/hr	HC g/hr	CO g/hr	NO _x g/hr	PM g/hr
1	131.3	50.94	10.87	758.39	694.15	296.42
2	99.6	36.08	56.26	170.03	590.22	51.35
3	66.2	25.47	79.63	112.67	400.09	22.48
4	15.0	12.74	531.22	534.77	76.00	132.70
5	92.6	36.08	18.29	951.06	519.97	172.68
6	69.6	23.34	42.04	68.15	412.81	23.24
7	46.5	14.84	52.15	59.72	280.69	18.32
8	0.8	2.12	45.49	89.11	20.30	10.61

Mode g/lb fuel						
Mode	HP	Fuel lb/lb	HC g/lb	CO g/lb	NO _x g/lb	PM g/lb
1	131.3	NA	0.21	14.89	13.63	5.82
2	99.6	NA	1.56	4.71	16.36	1.42
3	66.2	NA	3.13	4.42	15.71	0.88
4	15.0	NA	41.70	41.98	5.97	10.42
5	92.6	NA	0.51	26.36	14.41	4.79
6	69.6	NA	1.80	2.92	17.69	1.00
7	46.5	NA	3.51	4.02	18.91	1.23
8	0.8	NA	21.46	42.03	9.58	5.00

Mode g/bhp-hr						
Mode	HP	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
1	131.3	0.388	0.083	5.774	5.285	2.257
2	99.6	0.362	0.565	1.708	5.928	0.516
3	66.2	0.385	1.203	1.702	6.042	0.339
4	15.0	0.847	35.334	35.570	5.055	8.826
5	92.6	0.390	0.197	10.270	5.615	1.865
6	69.6	0.335	0.604	0.979	5.929	0.334
7	46.5	0.319	1.121	1.283	6.031	0.394
8	0.8	NA	NA	NA	NA	NA

8-Mode Weighted	BSFC lb/hp-hr	HC g/bhp-hr	CO g/bhp-hr	NO _x g/bhp-hr	PM g/bhp-hr
	0.308	1.390	4.933	5.735	1.369

11. Analysis and Conclusions

Emission data were taken from a John Deere 6068T production, 1990 model year, off-highway, heavy-duty diesel engine with the injection timing fixed at both a production and retarded position. Through injection timing retardation, the HD-FTP transient test showed NO_x and PM changes of -47.7% and 144.9% respectively, while the steady-state (8-mode) test showed changes of -46.1% and 158.1% for NO_x and PM.

While the engine injection timing remained in the retarded condition, the production injectors were replaced with "modified" injectors. These "modified" injectors were actually experimental injectors provided by John Deere. They were designed to provide better targeting of the fuel spray plume at retarded injection timings.

In comparison to the retarded engine configuration using production injectors, the "modified" injectors showed NO_x and PM changes of 15.6% and -20.5% respectively, over the steady-state test. Similarly, the HD-FTP transient test showed changes of 6.9% and -18.3% for NO_x and PM, respectively. HC and CO were also reduced over the steady-state and HD-FTP transient tests. All of the data mentioned above are shown in the following table (Table 11.1):

Table 11.1
Emissions Summary For John Deere 6068T Engine

HD-FTP Transient Test Emission Results				
Engine Configuration	HC	CO	NO _x	PM
	g/bhp-hr (g/kW-hr)			
Production Injection Timing, Production Injectors	0.858 (1.151)	3.606 (4.836)	10.808 (14.494)	0.405 (0.543)
Retarded Injection Timing, Production Injectors	1.580 (2.119)	5.433 (7.286)	5.650 (7.577)	0.992 (1.330)
Retarded Injection Timing, Modified Injectors	0.839 (1.125)	4.262 (5.715)	6.038 (8.097)	0.810 (1.086)

8-Mode Steady State Test Emission Results				
Engine Configuration	HC	CO	NO _x	PM
	g/bhp-hr (g/kW-hr)			
Production Injection Timing, Production Injectors	0.427 (0.573)	3.144 (4.216)	11.758 (15.767)	0.422 (0.566)
Retarded Injection Timing, Production Injectors	0.933 (1.251)	4.770 (6.397)	6.340 (8.502)	1.089 (1.460)
Retarded Injection Timing, Modified Injectors	0.774 (1.038)	3.564 (4.779)	7.327 (9.826)	0.866 (1.161)

Finally, a Ford New Holland production, 1991 model year, off-highway, heavy-duty diesel engine was emission tested with the injection timing fixed at both a production and retarded position. As with the John Deere engine, NO_x was reduced while HC, CO, and PM increased over the HD-FTP transient test due to the injection timing retardation.

Through injection timing retardation, the HD-FTP transient test showed NO_x and PM changes of -33.4% and 39.9% respectively, while the steady-state test showed changes of -36.4% and 36.0% for NO_x and PM. HC and CO were also reduced over the steady-state and HD-FTP transient tests (with the exception of CO for the steady-state test). The results for this engine are summarized in the following table (Table 11.2):

Table 11.2
Emissions Summary For Ford New Holland Engine

HD-FTP Transient Test Emission Results				
Engine Configuration	HC	CO	NO _x	PM
	g/bhp-hr (g/kW-hr)			
Production Injection Timing	2.116 (2.838)	5.288 (7.091)	10.590 (14.201)	0.902 (1.210)
Retarded Injection Timing	3.639 (4.880)	5.902 ¹ (7.915) ¹	7.055 (9.461)	1.262 (1.692)

8-Mode Steady State Test Emission Results				
Engine Configuration	HC	CO	NO _x	PM
	g/bhp-hr (g/kW-hr)			
Production Injection Timing	0.703 (0.943)	5.575 (7.476)	9.272 (12.434)	0.963 (1.291)
Retarded Injection Timing	1.397 (1.873)	4.767 (6.393)	5.895 (7.905)	1.310 (1.757)

¹This value incorporates data which was measured via continuous integration rather than a bag sample, which was the method used for all the other HD-FTP CO values reported. The author feels that this factor has an insignificant impact on the results.

Appendices

- A Fuel Specifications
- B Particulate Measurement Procedure
- C Federal On-Highway Smoke Testing Results Memorandum
- D Raw Transient Test Emission Data
- E Raw 8-Mode Steady-State Test Emission Data

A. Fuel Specifications

Laboratory Report

PHILLIPS 66 COMPANY

A SUBSIDIARY OF PHILLIPS PETROLEUM COMPANY

SPECIALTY CHEMICALS
P.O. BOX 968
BOERGER, TX 79008-0968DATE OF SHIPMENT
06-14-91CUSTOMER ORDER NO.
5700-09733INV./REQN. NO.
04339STRAILER NO.
452CUSTOM 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	130	130 Min.	ASTM D-93
Pour Point °F	-43	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%	493	
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

Steady State Particulate Measurement Example Using Full Exhaust Dilution

Introduction

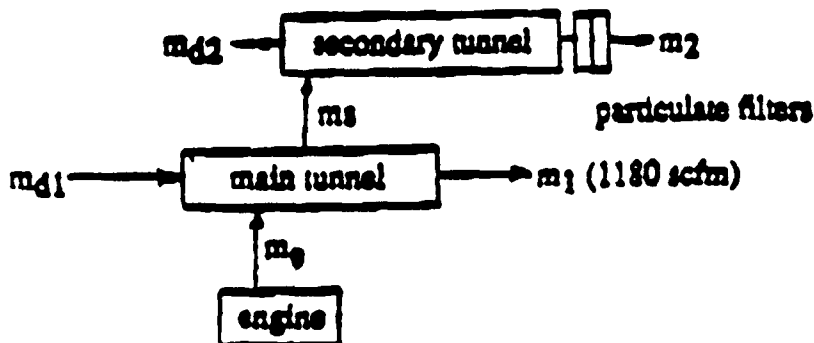
The primary objective of obtaining a particulate filter sample is to determine the engine exhaust particulate signature. Since this particulate signature can be as much a function of the measurement procedure as the engine design, specific guidelines are necessary to ensure that all laboratories perform similar measurements. Guidelines for flow measurement accuracies, particulate sampling options, filter parameters (size, composition, 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_{d1}), diluted exhaust sample from main tunnel (m_3), 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 lab 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, 1180 scfm primary tunnel flow, 10 minute sample time per mode. Values of m_0 , m_1 , m_2 sample, main dilution ratio and sample time are equivalent 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_0 (scfm)	m_1 (scfm)	% sample*	Main ** D. Ratio	Sample Time (min)
set	rd.	100	4.4	59	370	1.65	.14	3	10
set	rd.	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	rd.	100	4.2	52	370	1.65	.14	3	10
5	rd.	75	3.1	50	336	1.65	.14	4	10
6	rd.	50	3.2	46	307	1.65	.14	4	10
7	rd.	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, $100\% \cdot m_1 / 1180$

The % sample and m_1 data are design target suggestions that varied from test to test by $\pm 0.02\%$ (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 comping factor that prompts deviation from constant m_1 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, $1180/m_0$

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 quandry 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

C. Federal On-Highway Smoke Testing Results Memorandum



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

ANN ARBOR, MICHIGAN 48105

JUL 29 1993

OFFICE OF
AIR AND RADIATION

MEMORANDUM

SUBJECT: Heavy-Duty Engine Smoke Testing - Non-Road Engine Configurations, Injection Timing Effects

FROM: Mark H. Doorlag, Project Engineer
Technology Evaluation and Testing Support Branch

THRU: Thomas M. Baines, Senior Technical Advisor
Technology Evaluation and Testing Support Branch

TO: John F. Anderson, Chief
Technology Evaluation and Testing Support Branch

This memo contains smoke exhaust test results from the two non-road heavy-duty diesel engines (five engine configurations) described in Table 1. The 1990 model year John Deere 6068T was a turbocharged, in-line 6-cylinder, 6.8 L displacement heavy-duty diesel engine. Rated and peak torque speed for this direct injection engine were 2200 and 1300 RPM, respectively, with a rated horsepower of 139 hp (103.7 kW).

The 1991 model year Ford New Holland heavy-duty diesel engine was an in-line 6-cylinder, 7.5 L displacement, with no turbocharging. Rated speed and peak torque speeds for this direct injection engine were 2100 and 1200 RPM respectively, with a rated horsepower of 127 hp (94.7 kW).

The modified injectors used with the John Deere 6068T engine were actually experimental injectors provided by John Deere. They were designed to provide better targeting of the fuel spray plume at retarded injection timings.

A modified version of the Federal on-highway smoke test was performed on each of the three John Deere 6068T engine configurations and on each of the two Ford New Holland engine configurations. These tests were not intended to yield Federal Smoke Test Procedure results, but rather were performed in order to observe the directional change in smoke levels due to injection timing changes. Many tests failed the cycle statistic requirements and all of them utilized an exhaust pipe with a 4.5 inch diameter rather than the required 3.0 inch diameter. The results are presented immediately after Table 1.

Table 1
Engine Configuration Specifications

Manufacturer	John Deere			Ford New Holland
Model	6068T			----
Use	Log-Skidder			Ag. Tractor
Engine Serial Number	JDPRODT6068T35JL			358/117-91-89V
Model Year	1990			1991
Rated Power (bhp)	139			127
Rated Speed (rpm)	2200			2100
Peak Torque (ft-lb)	467			383
Peak Torque Speed (rpm)	1300			1200
Injection Timing (°BTDC)	15 ¹	~ 7 ²		8 ¹ ~ 4 ²
Injectors	Product. ³	Product. ³	Modified	Product. ³
Cylinders	6			6
Cylinder Configuration	in-line			in-line
Bore x Stroke (in)	4.19 x 5.0			4.4 x 5.0
Displacement (in ³ - liter)	414 - 6.8			456 - 7.5
Aspiration	turbo			natural
Aftercooling	none			none

¹Production injection timing.

²Retarded injection timing.

³Production.

1 John Deere 6068T Engine, Production Injection Timing, Production Injectors

The average acceleration, lug, and peak smoke values were determined to be 12.6%, 8.6%, and 22.2% respectively. The detailed Federal smoke test results are presented in Table 2.

2 John Deere 6068T Engine, Retarded Injection Timing, Production Injectors

The average acceleration, lug, and peak smoke values were determined to be 20.1%, 19.7%, and 41.1% respectively. Through the use of injection timing retardation, the HD-FTP smoke test showed acceleration, lug, and peak smoke increases of 59.5%, 129.1%, and 85.1% respectively. The detailed smoke test results are presented in Table 3.

3 John Deere 6068T Engine, Retarded Injection Timing, Modified Injectors

In comparison to the retarded engine configuration using production injectors, the "modified" injectors showed acceleration, lug, and peak smoke increases of 16.4%, 1.0%, and 14.6%, respectively, over the HD-FTP smoke test. Yet, the particulate levels (for the particulate results see the EPA Heavy-Duty Engine Testing Report, Non-Road Engine Configurations, Injection Timing Effects, Test Results - 1992, EPA-AA-TETSB-93-01) were lower using the "modified" injectors. This was an unexpected result that could not be explained with the data taken. The detailed smoke test results are presented in Table 4.

4 Ford New Holland Engine, Production Injection Timing

The average acceleration, lug, and peak smoke values were determined to be 11.2%, 26.2%, and 26.7% respectively. The detailed smoke test results are presented in Table 5.

5 Ford New Holland Engine, Retarded Injection Timing

The average acceleration, lug, and peak smoke values were determined to be 20.6%, 34.2%, and 34.8% respectively. Through the use of injection timing retardation, the HD-FTP smoke test showed acceleration, lug, and peak smoke increases of 83.9%, 30.5%, and 30.3% respectively. The detailed smoke test results are presented in Table 6.

6 Conclusions

The introduction of injection timing retardation to the John Deere 6068T engine produced an acceleration, lug, and peak smoke increase of 59.5%, 129.1%, and 85.1% respectively. Also, in comparison to the retarded engine configuration using production injectors, the "modified" injectors showed acceleration, lug, and peak smoke increases of 16.4%, 1.0%, and 14.6%, respectively, over the smoke test (see Table 7).

The introduction of injection timing retardation to the Ford New Holland engine produced an acceleration, lug, and peak smoke increase of 83.9%, 30.5%, and 30.3% respectively (see Table 8).

Table 2
John Deere 6068T Engine, Production Injection Timing,
Production Injectors Smoke Test Results

Test	Acceleration (%)	Lug (%)	Peak (%)	Linearity (rpm)
1	16.0	12.7	24.5	96.7
2	13.3	9.9	25.1	96.7
3	10.6	5.9	19.6	99.0
4				
Average	12.6	8.6	22.2	97.9

Table 3
John Deere 6068T Engine, Retarded Injection Timing,
Production Injectors Smoke Test Results

Test	Acceleration (%)	Lug (%)	Peak (%)	Linearity (rpm)
1 ¹	18.2	18.5	37.4	101.3
2	19.0	18.0	42.4	94.7
3 ¹	20.7	18.6	42.7	103.0
4 ¹	20.1	19.6	42.9	109.3
5 ¹	22.0	21.5	43.9	104.7
6 ¹	20.7	22.0	37.1	106.0
Average	20.1	19.7	41.1	103.2

¹The test failed cycle statistic requirements.

Table 4
John Deere 6068T Engine, Retarded Injection Timing,
Modified Injectors Smoke Test Results

Test	Acceleration (%)	Lug (%)	Peak (%)	Linearity (rpm)
1 ¹	26.6	22.1	51.5	109.0
2 ¹	25.0	22.1	47.5	104.3
3 ¹	21.7	18.6	44.3	109.7
4 ¹	21.1	17.8	44.9	109.3
5 ¹	23.2	19.3	48.0	109.0
6 ¹	22.5	19.4	46.1	109.0
Average	23.4	19.9	47.1	108.4

¹The test failed cycle statistic requirements.

Table 5
Ford New Holland Engine, Production Injection Timing
Smoke Test Results

Test	Acceleration (%)	Lug (%)	Peak (%)	Linearity (rpm)
1 ¹	11.4	26.2	26.8	102.3
2 ¹	10.7	26.2	26.6	102.7
3	12.2	26.3	27.0	92.3
4 ¹	10.3	26.1	26.4	100.0
Average	11.2	26.2	26.7	99.3

¹The test failed cycle statistic requirements.

Table 6
Ford New Holland Engine, Retarded Injection Timing
Smoke Test Results

Test	Acceleration (%)	Lug (%)	Peak (%)	Linearity (rpm)
1 ¹	18.5	34.9	35.6	107.7
2 ¹	23.7	36.0	36.8	107.7
3 ¹	21.2	32.9	33.5	106.7
4 ¹	18.9	32.8	33.4	106.0
Average	20.6	34.2	34.8	107.0

¹The test failed cycle statistic requirements.

Table 7
John Deere 6068T Engine Smoke Testing - Summary

Smoke Test Results			
Engine Configuration	Acceleration	Lug	Peak
	%		
Production Injection Timing, Production Injectors	12.6	8.6	22.2
Retarded Injection Timing, Production Injectors	20.1 ¹	19.7 ¹	41.1 ¹
Retarded Injection Timing, Modified Injectors	23.4 ¹	19.9 ¹	47.1 ¹

¹These values incorporate some data from individual Federal smoke tests which were invalid due to speed deflections greater than 100 rpm.

Table 8
Ford New Holland Engine Smoke Testing - Summary

Federal On-Highway Smoke Test Results			
Engine Configuration	Acceleration	Lug	Peak
	%		
Production Injection Timing	11.2 ¹	26.2 ¹	26.7 ¹
Retarded Injection Timing	20.6 ¹	34.2 ¹	34.8 ¹

¹These values incorporate some data from individual Federal smoke tests which were invalid due to speed deflections greater than 100 rpm.

D. Raw Transient Test Emission Data

John Deere 6068T Engine, Production Injection Timing, Production Injectors
HD-FTP, Cold Start 1

HEAVY DUTY DIESEL TRANSIENT DIGALOG TEST DATE: 08/22/91 TIME: 17:26:31 PAGE: 1
DIESEL SUMMARY REPORT

HD-910247
999 JDPRODT6068T35JL 0
18 CIFE

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 H2O / Lb. Dry Air

EMISSION RESULTS	CS	HS	MTD 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	5.1218	.00000
(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	5.7488	.00000
(Limit: 8%)		
R-Square	.96827	.00000
(Limit: 0.91)		
WORK		
Actual	10.515	.000
(Limit: -15% to 5% Ref Bhp-Hr)		
Reference	10.713	.000
% Difference	-2.03%	.000

HD-910248
999 JDPRODT6068T35JL 0
1B HS1F

HEAVY DUTY DIESEL TRANSIENT DIGALOG TEST

DATE: 08/22/91 TIME: 17:33:39 PAGE: 7

DIESEL SUMMARY REPORT

John Deere 6068T Engine, Production Injection Timing, Production Injectors
HD-FTP, 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 H2O / Lb. Dry Air

EMISSION RESULTS	CS	HS	MTD 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	5.5038	5.5038
(Limit: 138 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	6.2298	6.2298
(Limit: 88)		
R-Square	.96300	.96300
(Limit: 0.91)		
WORK		
Actual	.000	10.449
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	10.711
% Difference	.00%	-2.65%

HD-910249
999 JDPRODT6068T35JL 0
1B H03F

HEAVY DUTY DIESEL TRANSIENT DIGALOG TEST DATE: 08/22/91 TIME: 17:37:11 PAGE: 1

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 H2O / 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	3.357
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	5.5938	5.5938
(Limit: 138 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	6.3508	6.3508
(Limit: 88)		
R-Square	.96154	.96154
(Limit: 0.91)		
WORK		
Actual	.000	10.426
(Limit: -158-58 Ref Bhp-Hr)		
Reference	.000	10.733
% Difference	.00%	-2.86%

John Deere 6068T Engine, Production Injection Timing, Production Injectors
HD-FTP, Hot Start 2

HD-910259
999 JDPRODT6068T35JL 0
1B CS#3

HEAVY DUTY DIESEL TRANSIENT DIGALOG TEST
DIESEL SUMMARY REPORT

DATE: 08/28/91 TIME: 13:52:54 PAGE: 1

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 H2O / Lb. Dry Air

EMISSION RESULTS	CS	HS	MTD 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	10.713	.000
% Difference	-1.79%	.000%

John Deere 6068T Engine, Production Injection Timing, Production Injectors
HD-FTP, Cold Start 2

HD-910260
999 JDPRODT6068T35JL 0
18 HS55

HEAVY DUTY DIESEL TRANSIENT DIGALOG TEST DATE: 08/28/91 TIME: 13:59:40 PAGE: 1
DIESEL SUMMARY REPORT

John Deere 6068T Engine, Production Injection Timing, Production Injectors
HD-FTP, Hot Start 3

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 H2O / 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	5.6088	5.6088
(Limit: 138 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	6.3228	6.3228
(Limit: 88)		
R-Square	.96197	.96197
(Limit: 0.91)		
WORK		
Actual	.000	10.443
(Limit: -15%-5% Ref Bhp-Hr)		
Reference	.000	10.711
% Difference	.00%	-2.10%

HD-910261
999 JDPRODT6068T35JL 0
18 HS86

HEAVY DUTY DIESEL TRANSIENT DIGALOG TEST DATE: 08/28/91 TIME: 14:05:45 PAGE: 1
DIESEL SUMMARY REPORT

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 H2O / 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	5.7178	5.7178
(Limit: 138 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	6.4498	6.4498
(Limit: 88)		
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%

John Deere 6068T Engine, Production Injection Timing, Production Injectors
HD-FTP, Hot Start 4

HD920035
999 JDPRODT6068T35JL 0
1B CS1R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/06/92 TIME: 14:11:07 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920035 Manufacturer: EXPERIMENTAL
Test Date/Time: 2-26-92 8:35 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA:

Barometer: 28.86 "HG
Dry Bulb Temperature: 78.50 F
Absolute Humidity: 50.33 Grains H2O/Lbs Dry Air

EMISSION RESULTS: CS

HC (INTEGRATED):
Background, PPM 3.03
Exhaust+Bkg, Gms 23.29
Net, Gm/Bhp-Hr 2.204

CO (BAG):
Background, PPM .00
Exhaust+Bkg, Gms 59.63
Net, Gms/Bhp-Hr 6.10

NOX (INTEGRATED):
Background, PPM .26
Exhaust+Bkg, Gms 59.69
Net, Gms/Bhp-Hr 5.694

CO2 (BAG)
Background, PPM .031
Exhaust+Bkg, Gms 6510.88
Net, Gms/Bhp-Hr 605.7

PARTICULATE:
Secondary Tare, Gms .156380
Secondary Part, Gms .156593
Primary Tare, Gms .155841
Primary Part, Gms .168147
Total, Gms/Bhp-Hr 1.13

FUEL CONSUMPTION:
Lbs/Carbon Balance 4.129
Lbs/Bhp-Hr .423
Lbs/Measured 4.536

BRAKE HORSEPOWER-HOUR: 9.769

CYCLE STATISTICS: CS

SPEED:
Number 1175
Slope .99518
(Limit: 0.97-1.03)
Y-Intercept 7.954
(Limit: +/-50 RPM)
Std Error 43.943
(Limit: 100 RPM)
R-Square .99295
(Limit: 0.97)

TORQUE:
Number 997
Slope .96734
(Limit: 0.77/0.83-1.03)
Y-Intercept -5.948
(Limit: +/-15 Ft-Lbs)
Std Error 6.8874
(Limit: 13% Max Eng Tq)
R-Square .93461
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .95781
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.512
(Limit: +/-5 BHP)
Std Error 7.0694
(Limit: 8%)
R-Square .94734
(Limit: 0.91)

WORK:
Actual 9.769
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -4.51%

John Deere 6068T Engine, Retarded Injection Timing, Production Injectors
HD-FTP, Cold Start 1

HD920036
999 JDPRODT6068T35JL 0
1B HS1R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/06/92 TIME: 14:13:41 PAGE: 6

DIESEL SUMMARY REPORT

John Deere 6068T Engine, Retarded Injection Timing, Production Injectors
HD-FTP, Hot Start I

Test Number: HD-920036 Manufacturer: EXPERIMENTAL
Test Date/Time: 2-26-92 9:16 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA:

Barometer: 28.86 "HG
Dry Bulb Temperature: 78.90 F
Absolute Humidity: 107.02 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 4.84
Exhaust+Bkg, Gms 18.39
Net, Gm/Bhp-Hr 1.616

CO (BAG):
Background, PPM .00
Exhaust+Bkg, Gms 52.42
Net, Gms/Bhp-Hr 5.44

NOX (INTEGRATED):
Background, PPM 1.03
Exhaust+Bkg, Gms 51.72
Net, Gms/Bhp-Hr 5.634

CO2 (BAG)
Background, PPM .033
Exhaust+Bkg, Gms 6223.61
Net, Gms/Bhp-Hr 582.3

PARTICULATE:
Secondary Tare, Gms .154985
Secondary Part, Gms .155121
Primary Tare, Gms .157527
Primary Part, Gms .168359
Total, Gms/Bhp-Hr 1.00

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.898
Lbs/Bhp-Hr .405
Lbs/Measured 4.111

BRAKE HORSEPOWER-HOUR: 9.630

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99443
(Limit: 0.97-1.03)
Y-Intercept 7.803
(Limit: +-50 RPM)
Std Error 43.909
(Limit: 100 RPM)
R-Square .99295
(Limit: 0.97)

TORQUE:
Number 997
Slope .96688
(Limit: 0.77/0.83-1.03)
Y-Intercept -8.447
(Limit: +-15 Ft-Lbs)
Std Error 7.168
(Limit: 13% Max Eng Tq)
R-Square .92950
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .95546
(Limit: 0.87/0.89-1.03)
Y-Intercept -2.140
(Limit: +-5 BHP)
Std Error 7.307
(Limit: 8%)
R-Square .94367
(Limit: 0.91)

WORK:
Actual 9.630
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -5.87%

John Deere 6068T Engine, Retarded Injection Timing, Production Injectors
HD-FTP, Hot Start 2

HD920037
999 JDPRODT6068T35JL 0
1B HS2R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/07/92 TIME: 06:41:42 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920037 Manufacturer: EXPERIMENTAL
Test Date/Time: 2-26-92 9:57 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA:

Barometer: 28.84 "HG
Dry Bulb Temperature: 78.90 F
Absolute Humidity: 59.46 Grains H2O/Lbs Dry Air

MISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 5.15
Exhaust+Bkg, Gms 16.97
Net, Gm/Bhp-Hr 1.436

CO (BAG):
Background, PPM .00
Exhaust+Bkg, Gms 47.70
Net, Gms/Bhp-Hr 4.91

COX (INTEGRATED):
Background, PPM .77
Exhaust+Bkg, Gms 57.20
Net, Gms/Bhp-Hr 5.506

CO2 (BAG)
Background, PPM .031
Exhaust+Bkg, Gms 6154.80
Net, Gms/Bhp-Hr 572.9

PARTICULATE:
Secondary Tare, Gms .155656
Secondary Part, Gms .155768
Primary Tare, Gms .157392
Primary Part, Gms .167566
Total, Gms/Bhp-Hr .93

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.865
Lbs/Bhp-Hr .397
Lbs/Measured 4.111

BRAKE HORSEPOWER-HOUR: 9.725

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99481
(Limit: 0.97-1.03)
Y-Intercept 6.796
(Limit: +/-50 RPM)
Std Error 37.947
(Limit: 100 RPM)
R-Square .99473
(Limit: 0.97)

TORQUE:
Number 997
Slope .97259
(Limit: 0.77/0.83-1.03)
Y-Intercept -7.712
(Limit: +/-15 Ft-Lbs)
Std Error 6.8798
(Limit: 13% Max Eng Tq)
R-Square .93542
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .95920
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.780
(Limit: +/-5 BHP)
Std Error 7.1718
(Limit: 8%)
R-Square .94603
(Limit: 0.91)

WORK:
Actual 9.725
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -4.94%

HD920040
999 JDPRODT6068T35JL 0
1B CS2R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/06/92 TIME: 14:28:34 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920040 Manufacturer: EXPERIMENTAL
Test Date/Time: 2-27-92 8:46 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA:

Barometer: 28.77 "HG
Dry Bulb Temperature: 75.60 F
Absolute Humidity: 58.94 Grains H2O/Lbs Dry Air

EMISSION RESULTS: CS

HC (INTEGRATED):
Background, PPM 3.94
Exhaust+Bkg, Gms 20.54
Net, Gm/Bhp-Hr 1.871

CO (BAG):
Background, PPM .00
Exhaust+Bkg, Gms 60.27
Net, Gms/Bhp-Hr 6.17

NOX (INTEGRATED):
Background, PPM .51
Exhaust+Bkg, Gms 61.28
Net, Gms/Bhp-Hr 5.926

CO2 (BAG)
Background, PPM .031
Exhaust+Bkg, Gms 6762.32
Net, Gms/Bhp-Hr 632.5

PARTICULATE:
Secondary Tare, Gms .157116
Secondary Part, Gms .157255
Primary Tare, Gms .152955
Primary Part, Gms .161142
Total, Gms/Bhp-Hr 1.05

FUEL CONSUMPTION:
Lbs/Carbon Balance 4.300
Lbs/Bhp-Hr .440
Lbs/Measured 4.678

BRAKE HORSEPOWER-HOUR: 9.768

CYCLE STATISTICS: CS

SPEED:
Number 1175
Slope .99661
(Limit: 0.97-1.03)
Y-Intercept 8.167
(Limit: +-50 RPM)
Std Error 44.125
(Limit: 100 RPM)
R-Square .99292
(Limit: 0.97)

TORQUE:
Number 997
Slope .96496
(Limit: 0.77/0.83-1.03)
Y-Intercept -5.107
(Limit: +-15 Ft-Lbs)
Std Error 6.168%
(Limit: 13% Max Eng Tq)
R-Square .94662
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .95656
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.186
(Limit: +-5 BHP)
Std Error 6.608%
(Limit: 8%)
R-Square .95357
(Limit: 0.91)

WORK:
Actual 9.768
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -4.52%

John Deere 6068T Engine, Retarded Injection Timing, Production Injectors
HD-FTP, Cold Start 2

HD920041
999 JDPRODT6068T35JL 0
1B HS3R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/06/92 TIME: 14:30:51 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920041 Manufacturer: EXPERIMENTAL
Test Date/Time: 2-27-92 9:28 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA:

Barometer: 28.77 "HG
Dry Bulb Temperature: 77.80 F
Absolute Humidity: 59.39 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 3.94
Exhaust+Bkg, Gms 15.85
Net, Gm/Bhp-Hr 1.390

CO (BAG):
Background, PPM .00
Exhaust+Bkg, Gms 50.69
Net, Gms/Bhp-Hr 5.19

NOX (INTEGRATED):
Background, PPM .26
Exhaust+Bkg, Gms 57.56
Net, Gms/Bhp-Hr 5.611

CO2 (BAG)
Background, PPM .033
Exhaust+Bkg, Gms 6379.82
Net, Gms/Bhp-Hr 588.3

PARTICULATE:
Secondary Tare, Gms .155330
Secondary Part, Gms .155426
Primary Tare, Gms .153587
Primary Part, Gms .160992
Total, Gms/Bhp-Hr .95

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.988
Lbs/Bhp-Hr .408
Lbs/Measured 4.253

BRAKE HORSEPOWER-HOUR: 9.774

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99667
(Limit: 0.97-1.03)
Y-Intercept 6.997
(Limit: +-50 RPM)
Std Error 38.105
(Limit: 100 RPM)
R-Square .99471
(Limit: 0.97)

TORQUE:
Number 997
Slope .97093
(Limit: 0.77/0.83-1.03)
Y-Intercept -6.428
(Limit: +-15 Ft-Lbs)
Std Error 6.517
(Limit: 13% Max Eng Tq)
R-Square .94147
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .95846
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.373
(Limit: +-5 BHP)
Std Error 6.972
(Limit: 8%)
R-Square .94877
(Limit: 0.91)

WORK:
Actual 9.774
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -4.46%

John Deere 6068T Engine, Retarded Injection Timing, Production Injectors
HD-FTP, Hot Start 3

HD920042
999 JDPRODT6068T35JL 0
1B HS4R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/06/92 TIME: 14:33:02 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920042 Manufacturer: EXPERIMENTAL
Test Date/Time: 2-27-92 10: 8 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA:

Barometer: 28.78 "HG
Dry Bulb Temperature: 81.80 F
Absolute Humidity: 60.26 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 4.24
Exhaust+Bkg, Gms 15.52
Net, Gm/Bhp-Hr 1.357

CO (BAG):
Background, PPM .00
Exhaust+Bkg, Gms 47.53
Net, Gms/Bhp-Hr 4.93

NOX (INTEGRATED):
Background, PPM .51
Exhaust+Bkg, Gms 57.52
Net, Gms/Bhp-Hr 5.648

CO2 (BAG)
Background, PPM .030
Exhaust+Bkg, Gms 6210.22
Net, Gms/Bhp-Hr 587.6

PARTICULATE:
Secondary Tare, Gms .157804
Secondary Part, Gms .157944
Primary Tare, Gms .156801
Primary Part, Gms .164095
Total, Gms/Bhp-Hr .94

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.927
Lbs/Bhp-Hr .407
Lbs/Measured 4.253

BRAKE HORSEPOWER-HOUR: 9.641

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99526
(Limit: 0.97-1.03)
Y-Intercept 8.038
(Limit: +-50 RPM)
Std Error 43.932
(Limit: 100 RPM)
R-Square .99296
(Limit: 0.97)

TORQUE:
Number 997
Slope .97023
(Limit: 0.77/0.83-1.03)
Y-Intercept -8.823
(Limit: +-15 Ft-Lbs)
Std Error 6.848
(Limit: 13% Max Eng Tq)
R-Square .93567
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .95902
(Limit: 0.87/0.89-1.03)
Y-Intercept -2.172
(Limit: +-5 BHP)
Std Error 7.110
(Limit: 8%)
R-Square .94688
(Limit: 0.91)

WORK:
Actual 9.641
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -5.76%

John Deere 6068T Engine, Retarded Injection Timing, Production Injectors
HD-FTP, Hot Start 4

HD920048
999 JDPRODT6068T35JL 0
1B CSN2

HEAVY DUTY DIESEL TRANSIENT TEST
DIESEL SUMMARY REPORT

DATE: 04/06/92 TIME: 14:43:40 PAGE: 6

Test Number: HD-920048 Manufacturer: EXPERIMENTAL
Test Date/Time: 3- 3-92 10: 7 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA:

Barometer: 29.29 "HG
Dry Bulb Temperature: 83.70 F
Absolute Humidity: 63.78 Grains H2O/Lbs Dry Air

EMISSION RESULTS: CS

HC (INTEGRATED):
Background, PPM 4.84
Exhaust+Bkg, Gms 13.99
Net, Gm/Bhp-Hr 1.135

CO (BAG):
Background, PPM .00
Exhaust+Bkg, Gms 50.00
Net, Gms/Bhp-Hr 5.08

NOX (INTEGRATED):
Background, PPM .77
Exhaust+Bkg, Gms 61.27
Net, Gms/Bhp-Hr 5.907

CO2 (BAG)
Background, PPM .035
Exhaust+Bkg, Gms 6614.20
Net, Gms/Bhp-Hr 604.1

PARTICULATE:
Secondary Tare, Gms .153219
Secondary Part, Gms .153384
Primary Tare, Gms .153168
Primary Part, Gms .159948
Total, Gms/Bhp-Hr .89

FUEL CONSUMPTION:
Lbs/Carbon Balance 4.112
Lbs/Bhp-Hr .418
Lbs/Measured 4.395

BRAKE HORSEPOWER-HOUR: 9.833

CYCLE STATISTICS: CS

SPEED:
Number 1175
Slope .99706
(Limit: 0.97-1.03)
Y-Intercept 7.647
(Limit: +-50 RPM)
Std Error 43.532
(Limit: 100 RPM)
R-Square .99311
(Limit: 0.97)

TORQUE:
Number 997
Slope .97565
(Limit: 0.77/0.83-1.03)
Y-Intercept -6.333
(Limit: +-15 Ft-Lbs)
Std Error 6.464
(Limit: 13% Max Eng Tq)
R-Square .94288
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .96496
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.428
(Limit: +-5 BHP)
Std Error 6.846
(Limit: 8%)
R-Square .95114
(Limit: 0.91)

WORK:
Actual 9.833
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -3.88%

John Deere 6068T Engine, Retarded Injection Timing, Modified Injectors
HD-FTP, Cold Start 1

HD920049
999 JDPRODT6068T35JL 0
1B HSNJ

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/16/92 TIME: 12:21:31 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920049 Manufacturer: EXPERIMENTAL
Test Date/Time: 3- 3-92 10:47 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA:

Barometer: 29.28 *HG
Dry Bulb Temperature: 85.80 F
Absolute Humidity: 62.63 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):

Background, PPM 4.84
Exhaust+Bkg, Gms 10.58
Net, Gm/Bhp-Hr .791

CO (BAG):

Background, PPM .63
Exhaust+Bkg, Gms 41.09
Net, Gms/Bhp-Hr 4.12

NOX (INTEGRATED):

Background, PPM .77
Exhaust+Bkg, Gms 61.23
Net, Gms/Bhp-Hr 5.906

CO2 (BAG)

Background, PPM .033
Exhaust+Bkg, Gms 6276.54
Net, Gms/Bhp-Hr 576.6

PARTICULATE:

Secondary Tare, Gms .158028
Secondary Part, Gms .158108
Primary Tare, Gms .158470
Primary Part, Gms .164425
Total, Gms/Bhp-Hr .79

FUEL CONSUMPTION:

Lbs/Carbon Balance 3.897
Lbs/Bhp-Hr .398
Lbs/Measured 4.111

BRAKE HORSEPOWER-HOUR: 9.800

CYCLE STATISTICS:

HS

SPEED:

Number 1175
Slope .99689
(Limit: 0.97-1.03)
Y-Intercept 6.591
(Limit: +-50 RPM)
Std Error 37.855
(Limit: 100 RPM)
R-Square .99478
(Limit: 0.97)

TORQUE:

Number 997
Slope .97765
(Limit: 0.77/0.83-1.03)
Y-Intercept -7.332
(Limit: +-15 Ft-Lbs)
Std Error 6.534
(Limit: 13% Max Eng Tq)
R-Square .94194
(Limit: 0.85/0.88)

POWER:

Number 997
Slope .96490
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.583
(Limit: +-5 BHP)
Std Error 7.051
(Limit: 8%)
R-Square .94832
(Limit: 0.91)

WORK:

Actual 9.800
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -4.20%

John Deere 6068T Engine, Retarded Injection Timing, Modified Injectors
HD-FIP, Hot Start 1

HD920050
999 JDPRODT6068T35JL 0
1B HSN4

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/06/92 TIME: 14:45:28 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920050 Manufacturer: EXPERIMENTAL
Test Date/Time: 3- 3-92 11:26 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA:

Barometer: 29.28 "HG
Dry Bulb Temperature: 84.00 F
Absolute Humidity: 63.56 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 5.45
Exhaust+Bkg, Gms 10.19
Net, Gm/Bhp-Hr .716

CO (BAG):
Background, PPM .63
Exhaust+Bkg, Gms 39.50
Net, Gms/Bhp-Hr 3.96

NOX (INTEGRATED):
Background, PPM .77
Exhaust+Bkg, Gms 61.23
Net, Gms/Bhp-Hr 5.930

CO2 (BAG)
Background, PPM .033
Exhaust+Bkg, Gms 6279.87
Net, Gms/Bhp-Hr 577.9

PARTICULATE:
Secondary Tare, Gms .158887
Secondary Part, Gms .159050
Primary Tare, Gms .157479
Primary Part, Gms .163105
Total, Gms/Bhp-Hr .75

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.896
Lbs/Bhp-Hr .398
Lbs/Measured 4.111

BRAKE HORSEPOWER-HOUR: 9.782

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99639
(Limit: 0.97-1.03)
Y-Intercept 6.446
(Limit: +-50 RPM)
Std Error 37.643
(Limit: 100 RPM)
R-Square .99483
(Limit: 0.97)

TORQUE:
Number 997
Slope .98083
(Limit: 0.77/0.83-1.03)
Y-Intercept -8.062
(Limit: +-15 Ft-Lbs)
Std Error 6.547
(Limit: 13% Max Eng Tq)
R-Square .94207
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .96576
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.719
(Limit: +-5 BHP)
Std Error 7.062
(Limit: 8%)
R-Square .94825
(Limit: 0.91)

WORK:
Actual 9.782
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -4.38%

John Deere 6068T Engine, Retarded Injection Timing, Modified Injectors
HD-FTP, Hot Start 2

HD920051 999 JDPRODT6068T35JL 0 1B CS3N HEAVY DUTY DIESEL TRANSIENT TEST DATE: 04/06/92 TIME: 14:50:58 PAGE: 6
DIESEL SUMMARY REPORT

Test Number: HD-920051 Manufacturer: EXPERIMENTAL
Test Date/Time: 3- 4-92 9:23 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA:

Barometer: 29.27 "HG
Dry Bulb Temperature: 77.80 F
Absolute Humidity: 59.46 Grains H2O/Lbs Dry Air

EMISSION RESULTS: CS

HC (INTEGRATED):
Background, PPM 3.94
Exhaust+Bkg, Gms 14.71
Net, Gm/Bhp-Hr 1.261

CO (BAG):
Background, PPM .63
Exhaust+Bkg, Gms 53.14
Net, Gms/Bhp-Hr 5.32

NOX (INTEGRATED):
Background, PPM .26
Exhaust+Bkg, Gms 66.49
Net, Gms/Bhp-Hr 6.446

CO2 (BAG)
Background, PPM .041
Exhaust+Bkg, Gms 6875.39
Net, Gms/Bhp-Hr 620.4

PARTICULATE:
Secondary Tare, Gms .157429
Secondary Part, Gms .157580
Primary Tare, Gms .157535
Primary Part, Gms .164536
Total, Gms/Bhp-Hr .94

FUEL CONSUMPTION:
Lbs/Carbon Balance 4.228
Lbs/Bhp-Hr .430
Lbs/Measured 4.465

BRAKE HORSEPOWER-HOUR: 9.839

CYCLE STATISTICS: CS

SPEED:
Number 1175
Slope .99683
(Limit: 0.97-1.03)
Y-Intercept 7.892
(Limit: +/-50 RPM)
Std Error 43.852
(Limit: 100 RPM)
R-Square .99301
(Limit: 0.97)

TORQUE:
Number 997
Slope .97648
(Limit: 0.77/0.83-1.03)
Y-Intercept -5.892
(Limit: +/-15 Ft-Lbs)
Std Error 6.290%
(Limit: 13% Max Eng Tq)
R-Square .94584
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .96156
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.196
(Limit: +/-5 BHP)
Std Error 6.728%
(Limit: 8%)
R-Square .95241
(Limit: 0.91)

WORK:
Actual 9.839
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -3.82%

John Deere 6068T Engine, Retarded Injection Timing, Modified Injectors
HD-FTP, Cold Start 2

D920052
99 JDPRODT6068T35JL 0
B HS5N

HEAVY DUTY DIESEL TRANSIENT TEST
DIESEL SUMMARY REPORT

DATE: 04/06/92 TIME: 14:56:25 PAGE: 6

John Deere 6068T Engine, Retarded Injection Timing, Modified Injectors
HD-FTP, Hot Start 3

st Number: HD-920052 Manufacturer: EXPERIMENTAL
st Date/Time: 3- 4-92 10: 3 Engine ID: 999 JDPRODT6068T35JL 0

BIENT DATA:

rometer: 29.27 "HG
y Bulb Temperature: 85.60 F
bsolute Humidity: 62.18 Grains H2O/Lbs Dry Air

MISSION RESULTS: HS

(INTEGRATED):
Background, PPM 5.15
Exhaust+Bkg, Gms 10.43
Net, Gm/Bhp-Hr .765

(BAG):
Background, PPM 2.50
Exhaust+Bkg, Gms 42.66
Net, Gms/Bhp-Hr 4.09

(INTEGRATED):
Background, PPM .77
Exhaust+Bkg, Gms 62.79
Net, Gms/Bhp-Hr 6.121

(BAG)
Background, PPM .048
Exhaust+Bkg, Gms 6564.62
Net, Gms/Bhp-Hr 582.2

ARTICULATE:
Secondary Tare, Gms .155759
Secondary Part, Gms .155871
Primary Tare, Gms .153303
Primary Part, Gms .159158
Total, Gms/Bhp-Hr .79

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.890
Lbs/Bhp-Hr .401
Lbs/Measured 4.182

AKE HORSEPOWER-HOUR: 9.691

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99583
(Limit: 0.97-1.03)
Y-Intercept 7.727
(Limit: +-50 RPM)
Std Error 43.932
(Limit: 100 RPM)
R-Square .99297
(Limit: 0.97)

TORQUE:
Number 997
Slope .97595
(Limit: 0.77/0.83-1.03)
Y-Intercept -8.697
(Limit: +-15 Ft-Lbs)
Std Error 6.721
(Limit: 13% Max Eng Tq)
R-Square .93858
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .96168
(Limit: 0.87/0.89-1.03)
Y-Intercept -2.018
(Limit: +-5 BHP)
Std Error 6.996
(Limit: 8%)
R-Square .94875
(Limit: 0.91)

WORK:
Actual 9.691
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -5.27%

HD920053
999 JDPRODT6068T35JL 0
1B HS6N

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/06/92 TIME: 14:58:55 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920053 Manufacturer: EXPERIMENTAL
Test Date/Time: 3- 4-92 10:42 Engine ID: 999 JDPRODT6068T35JL 0

AMBIENT DATA:

Barometer: 29.27 "HG
Dry Bulb Temperature: 80.60 F
Absolute Humidity: 59.91 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 4.24
Exhaust+Bkg, Gms 10.36
Net, Gm/Bhp-Hr .822

CO (BAG):
Background, PPM 2.50
Exhaust+Bkg, Gms 43.44
Net, Gms/Bhp-Hr 4.21

NOX (INTEGRATED):
Background, PPM .26
Exhaust+Bkg, Gms 62.12
Net, Gms/Bhp-Hr 6.185

CO2 (BAG)
Background, PPM .044
Exhaust+Bkg, Gms 6600.19
Net, Gms/Bhp-Hr 599.7

PARTICULATE:
Secondary Tare, Gms .155375
Secondary Part, Gms .155432
Primary Tare, Gms .158355
Primary Part, Gms .163954
Total, Gms/Bhp-Hr .76

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.965
Lbs/Bhp-Hr .414
Lbs/Measured 4.182

BRAKE HORSEPOWER-HOUR: 9.588

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99397
(Limit: 0.97-1.03)
Y-Intercept 9.044
(Limit: +-50 RPM)
Std Error 49.477
(Limit: 100 RPM)
R-Square .99106
(Limit: 0.97)

TORQUE:
Number 997
Slope .97012
(Limit: 0.77/0.83-1.03)
Y-Intercept -9.618
(Limit: +-15 Ft-Lbs)
Std Error 7.696%
(Limit: 13% Max Eng Tq)
R-Square .92010
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .95735
(Limit: 0.87/0.89-1.03)
Y-Intercept -2.402
(Limit: +-5 BHP)
Std Error 7.868%
(Limit: 8%)
R-Square .93551
(Limit: 0.91)

WORK:
Actual 9.588
(Limit: -15%-5% Ref Bhp-Hr)
Reference 10.230
% Difference -6.28%

John Deere 6068T Engine, Retarded Injection Timing, Modified Injectors
HD-FTP, Hot Start 4

HD920084
30 NH358-117-92-89V 1
1B CS2D

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/15/92 TIME: 16:10:31 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920084 Manufacturer: FORD
Test Date/Time: 4-15-92 7:45 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 29.32 "HG
Dry Bulb Temperature: 83.00 F
Absolute Humidity: 64.90 Grains H2O/Lbs Dry Air

EMISSION RESULTS: CS

HC (INTEGRATED):
Background, PPM 5.25
Exhaust+Bkg, Gms 24.56
Net, Gm/Bhp-Hr 2.313

CO (BAG):
Background, PPM 2.36
Exhaust+Bkg, Gms 52.36
Net, Gms/Bhp-Hr 5.33

NOX (INTEGRATED):
Background, PPM .50
Exhaust+Bkg, Gms 106.23
Net, Gms/Bhp-Hr 11.047

CO2 (BAG)
Background, PPM .038
Exhaust+Bkg, Gms 6119.96
Net, Gms/Bhp-Hr 580.2

PARTICULATE:
Secondary Tare, Gms .158151
Secondary Part, Gms .158563
Primary Tare, Gms .156226
Primary Part, Gms .165790
Total, Gms/Bhp-Hr .94

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.758
Lbs/Bhp-Hr .405
Lbs/Measured 4.395

BRAKE HORSEPOWER-HOUR: 9.284

CYCLE STATISTICS:

CS

SPEED:
Number 1175
Slope .99984
(Limit: 0.97-1.03)
Y-Intercept 3.483
(Limit: +-50 RPM)
Std Error 17.146
(Limit: 100 RPM)
R-Square .99890
(Limit: 0.97)

TORQUE:
Number 994
Slope 1.00108
(Limit: 0.77/0.83-1.03)
Y-Intercept -4.640
(Limit: +-15 Ft-Lbs)
Std Error 7.810%
(Limit: 13% Max Eng Tq)
R-Square .93776
(Limit: 0.85/0.88)

POWER:
Number 994
Slope 1.00767
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.294
(Limit: +-5 BHP)
Std Error 7.139%
(Limit: 8%)
R-Square .94931
(Limit: 0.91)

WORK:
Actual 9.284
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.603
% Difference -3.32%

Ford New Holland Engine, Production Injection Timing
HD-FTP, Cold Start 1

DIESEL SUMMARY REPORT

Test Number: HD-920085 Manufacturer: FORD
Test Date/Time: 4-15-92 8:26 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 29.33 *HG
Dry Bulb Temperature: 84.70 F
Absolute Humidity: 63.45 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 4.50
Exhaust+Bkg, Gms 21.25
Net, Gm/Bhp-Hr 2.040

CO (BAG):
Background, PPM 2.58
Exhaust+Bkg, Gms 47.57
Net, Gms/Bhp-Hr 4.87

NOX (INTEGRATED):
Background, PPM 1.00
Exhaust+Bkg, Gms 104.55
Net, Gms/Bhp-Hr 10.927

CO2 (BAG)
Background, PPM .037
Exhaust+Bkg, Gms 5966.19
Net, Gms/Bhp-Hr 577.7

PARTICULATE:
Secondary Tare, Gms .152628
Secondary Part, Gms .152910
Primary Tare, Gms .155464
Primary Part, Gms .164773
Total, Gms/Bhp-Hr .92

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.665
Lbs/Bhp-Hr .402
Lbs/Measured 4.040

BRAKE HORSEPOWER-HOUR: 9.116

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99938
(Limit: 0.97-1.03)
Y-Intercept 3.063
(Limit: +-50 RPM)
Std Error 17.263
(Limit: 100 RPM)
R-Square .99887
(Limit: 0.97)

TORQUE:
Number 995
Slope .98793
(Limit: 0.77/0.83-1.03)
Y-Intercept -5.238
(Limit: +-15 Ft-Lbs)
Std Error 8.171
(Limit: 13% Max Eng Tq)
R-Square .93078
(Limit: 0.85/0.88)

POWER:
Number 995
Slope 1.00307
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.690
(Limit: +-5 BHP)
Std Error 7.434
(Limit: 8%)
R-Square .94496
(Limit: 0.91)

WORK:
Actual 9.116
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.603
Difference -5.07%

Ford New Holland Engine, Production Injection Timing
HD-FTP, Hot Start 1

HD920086
30 NH358-117-92-89V 1
1B HS4D

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/15/92 TIME: 16:22:18 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920086 Manufacturer: FORD
Test Date/Time: 4-15-92 9: 7 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 29.34 "HG
Dry Bulb Temperature: 85.10 F
Absolute Humidity: 65.34 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 4.80
Exhaust+Bkg, Gms 21.28
Net, Gm/Bhp-Hr 2.025

CO (BAG):
Background, PPM 2.15
Exhaust+Bkg, Gms 46.49
Net, Gms/Bhp-Hr 4.82

NOX (INTEGRATED):
Background, PPM 1.50
Exhaust+Bkg, Gms 97.30
Net, Gms/Bhp-Hr 10.104

CO2 (BAG)
Background, PPM .035
Exhaust+Bkg, Gms 5933.20
Net, Gms/Bhp-Hr 578.2

PARTICULATE:
Secondary Tare, Gms .154874
Secondary Part, Gms .155131
Primary Tare, Gms .156077
Primary Part, Gms .165592
Total, Gms/Bhp-Hr .94

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.665
Lbs/Bhp-Hr .402
Lbs/Measured 4.040

BRAKE HORSEPOWER-HOUR: 9.111

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99897
(Limit: 0.97-1.03)
Y-Intercept 2.865
(Limit: +-50 RPM)
Std Error 17.804
(Limit: 100 RPM)
R-Square .99880
(Limit: 0.97)

TORQUE:
Number 995
Slope .98983
(Limit: 0.77/0.83-1.03)
Y-Intercept -5.836
(Limit: +-15 Ft-Lbs)
Std Error 8.187%
(Limit: 13% Max Eng Tq)
R-Square .93076
(Limit: 0.85/0.88)

POWER:
Number 995
Slope 1.00450
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.829
(Limit: +-5 BHP)
Std Error 7.458%
(Limit: 8%)
R-Square .94478
(Limit: 0.91)

WORK:
Actual 9.111
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.603
% Difference -5.12%

Ford New Holland Engine, Production Injection Timing
HD-FTP, Hot Start 2

HD920090
30 NH358-117-92-89V 1
1B CS4D

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/17/92 TIME: 07:27:42 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920090 Manufacturer: FORD
Test Date/Time: 4-16-92 12:57 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 28.86 "HG
Dry Bulb Temperature: 81.70 F
Absolute Humidity: 83.35 Grains H2O/Lbs Dry Air

EMISSION RESULTS: CS

HC (INTEGRATED):
Background, PPM 4.05
Exhaust+Bkg, Gms 25.83
Net, Gm/Bhp-Hr 2.537

CO (BAG):
Background, PPM 2.79
Exhaust+Bkg, Gms 60.31
Net, Gms/Bhp-Hr 6.16

NOX (INTEGRATED):
Background, PPM 1.00
Exhaust+Bkg, Gms 102.90
Net, Gms/Bhp-Hr 11.156

CO2 (BAG)
Background, PPM .044
Exhaust+Bkg, Gms 6494.98
Net, Gms/Bhp-Hr 613.5

PARTICULATE:
Secondary Tare, Gms .151922
Secondary Part, Gms .152280
Primary Tare, Gms .151596
Primary Part, Gms .161585
Total, Gms/Bhp-Hr .99

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.967
Lbs/Bhp-Hr .429
Lbs/Measured 4.465

BRAKE HORSEPOWER-HOUR: 9.251

CYCLE STATISTICS: CS

SPEED:
Number 1175
Slope .99970
(Limit: 0.97-1.03)
Y-Intercept 2.871
(Limit: +-50 RPM)
Std Error 17.916
(Limit: 100 RPM)
R-Square .99879
(Limit: 0.97)

TORQUE:
Number 994
Slope .99343
(Limit: 0.77/0.83-1.03)
Y-Intercept -4.452
(Limit: +-15 Ft-Lbs)
Std Error 7.910
(Limit: 13% Max Eng Tq)
R-Square .93534
(Limit: 0.85/0.88)

POWER:
Number 994
Slope .99904
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.186
(Limit: +-5 BHP)
Std Error 7.119
(Limit: 8%)
R-Square .94875
(Limit: 0.91)

WORK:
Actual 9.251
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.603
% Difference -3.67%

Ford New Holland Engine, Production Injection Timing
HD-FTP, Cold Start 2

HD920091
30 NH358-117-92-89V 1
1B HS7D

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/17/92 TIME: 07:28:04 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920091 Manufacturer: FORD
Test Date/Time: 4-16-92 13:37 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 28.83 *HG
Dry Bulb Temperature: 83.70 F
Absolute Humidity: 64.81 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 5.10
Exhaust+Bkg, Gms 21.96
Net, Gm/Bhp-Hr 2.086

CO (BAG):
Background, PPM 2.58
Exhaust+Bkg, Gms 53.54
Net, Gms/Bhp-Hr 5.55

NOX (INTEGRATED):
Background, PPM 1.50
Exhaust+Bkg, Gms 97.02
Net, Gms/Bhp-Hr 10.079

CO2 (BAG)
Background, PPM .042
Exhaust+Bkg, Gms 6184.04
Net, Gms/Bhp-Hr 593.0

PARTICULATE:
Secondary Tare, Gms .158371
Secondary Part, Gms .158563
Primary Tare, Gms .151391
Primary Part, Gms .159887
Total, Gms/Bhp-Hr .86

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.759
Lbs/Bhp-Hr .413
Lbs/Measured 4.182

BRAKE HORSEPOWER-HOUR: 9.097

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99853
(Limit: 0.97-1.03)
Y-Intercept 2.979
(Limit: +-50 RPM)
Std Error 17.833
(Limit: 100 RPM)
R-Square .99880
(Limit: 0.97)

TORQUE:
Number 995
Slope .98658
(Limit: 0.77/0.83-1.03)
Y-Intercept -5.713
(Limit: +-15 Ft-Lbs)
Std Error 7.981
(Limit: 13% Max Eng Tq)
R-Square .93357
(Limit: 0.85/0.88)

POWER:
Number 995
Slope .99808
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.700
(Limit: +-5 BHP)
Std Error 7.269
(Limit: 8%)
R-Square .94675
(Limit: 0.91)

WORK:
Actual 9.097
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.603
% Difference -5.27%

Ford New Holland Engine, Production Injection Timing
HD-FTP, Hot Start 3

HD920092
30 NH358-117-92-89V 1
1B HS8D

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/17/92 TIME: 07:28:25 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920092 Manufacturer: FORD
Test Date/Time: 4-16-92 14:16 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 28.79 *HG
Dry Bulb Temperature: 83.70 F
Absolute Humidity: 62.30 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 4.95
Exhaust+Bkg, Gms 21.82
Net, Gm/Bhp-Hr 2.097

CO (BAG):
Background, PPM 1.93
Exhaust+Bkg, Gms 51.53
Net, Gms/Bhp-Hr 5.45

NOX (INTEGRATED):
Background, PPM 3.00
Exhaust+Bkg, Gms 95.02
Net, Gms/Bhp-Hr 9.565

CO2 (BAG)
Background, PPM .033
Exhaust+Bkg, Gms 5868.54
Net, Gms/Bhp-Hr 581.4

PARTICULATE:
Secondary Tare, Gms .159786
Secondary Part, Gms .159900
Primary Tare, Gms .157921
Primary Part, Gms .167215
Total, Gms/Bhp-Hr .97

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.659
Lbs/Bhp-Hr .405
Lbs/Measured 4.111

BRAKE HORSEPOWER-HOUR: 9.029

CYCLE STATISTICS:

HS

SPEED:

Number 1175
Slope .99847
(Limit: 0.97-1.03)
Y-Intercept 2.123
(Limit: +-50 RPM)
Std Error 13.153
(Limit: 100 RPM)
R-Square .99935
(Limit: 0.97)

TORQUE:

Number 995
Slope .98560
(Limit: 0.77/0.83-1.03)
Y-Intercept -6.397
(Limit: +-15 Ft-Lbs)
Std Error 8.053
(Limit: 13% Max Eng Tq)
R-Square .93233
(Limit: 0.85/0.88)

POWER:

Number 995
Slope .99600
(Limit: 0.87/0.89-1.03)
Y-Intercept -1.881
(Limit: +-5 BHP)
Std Error 7.536
(Limit: 8%)
R-Square .94276
(Limit: 0.91)

WORK:

Actual 9.029
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.603
% Difference -5.98%

Ford New Holland Engine, Production Injection Timing
HD-FTP, Hot Start 4

HD920107
30 NH358-117-92-89V 1
1B CS2R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 05/05/92 TIME: 10:29:25 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920107 Manufacturer: FORD
Test Date/Time: 4-23-92 14: 3 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 29.04 "HG
Dry Bulb Temperature: 81.70 F
Absolute Humidity: 53.75 Grains H2O/Lbs Dry Air

EMISSION RESULTS: CS

HC (INTEGRATED):
Background, PPM 5.15
Exhaust+Bkg, Gms 41.44
Net, Gm/Bhp-Hr 4.451

CO (BAG):
Background, PPM 1.50
Exhaust+Bkg, Gms 48.96
Net, Gms/Bhp-Hr 5.46

NOX (INTEGRATED):
Background, PPM 2.00
Exhaust+Bkg, Gms 73.73
Net, Gms/Bhp-Hr 7.665

CO2 (BAG)
Background, PPM .035
Exhaust+Bkg, Gms 5274.76
Net, Gms/Bhp-Hr 534.2

PARTICULATE:
Secondary Tare, Gms .157574
Secondary Part, Gms .158171
Primary Tare, Gms .157601
Primary Part, Gms .168272
Total, Gms/Bhp-Hr 1.57

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.270
Lbs/Bhp-Hr .378
Lbs/Measured 4.465

BRAKE HORSEPOWER-HOUR: 8.642

CYCLE STATISTICS: CS

SPEED:
Number 1175
Slope 1.00016
(Limit: 0.97-1.03)
Y-Intercept 2.789
(Limit: +-50 RPM)
Std Error 12.329
(Limit: 100 RPM)
R-Square .99944
(Limit: 0.97)

TORQUE:
Number 997
Slope .92466
(Limit: 0.77/0.83-1.03)
Y-Intercept .889
(Limit: +-15 Ft-Lbs)
Std Error 7.2118
(Limit: 13% Max Eng Tq)
R-Square .93868
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .93431
(Limit: 0.87/0.89-1.03)
Y-Intercept -.072
(Limit: +-5 BHP)
Std Error 6.7278
(Limit: 8%)
R-Square .94829
(Limit: 0.91)

WORK:
Actual 8.642
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.262
% Difference -6.69%

Ford New Holland Engine, Retarded Injection Timing
HD-FTP, Cold Start 1

HD920108
30 NH358-117-92-89V 1
1B HS3R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 05/05/92 TIME: 10:35:45 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920108 Manufacturer: FORD
Test Date/Time: 4-23-92 14:42 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 29.02 "HG
Dry Bulb Temperature: 83.40 F
Absolute Humidity: 55.65 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 5.45
Exhaust+Bkg, Gms 31.73
Net, Gm/Bhp-Hr 3.375

CO (BAG):
Background, PPM 1.72
Exhaust+Bkg, Gms 40.61
Net, Gms/Bhp-Hr 4.55

NOX (INTEGRATED):
Background, PPM 1.00
Exhaust+Bkg, Gms 61.63
Net, Gms/Bhp-Hr 6.712

CO2 (BAG)
Background, PPM .035
Exhaust+Bkg, Gms 5197.19
Net, Gms/Bhp-Hr 535.8

PARTICULATE:
Secondary Tare, Gms .159452
Secondary Part, Gms .159888
Primary Tare, Gms .158480
Primary Part, Gms .167165
Total, Gms/Bhp-Hr 1.17

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.186
Lbs/Bhp-Hr .376
Lbs/Measured 4.040

BRAKE HORSEPOWER-HOUR: 8.471

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99943
(Limit: 0.97-1.03)
Y-Intercept 2.563
(Limit: +-50 RPM)
Std Error 12.247
(Limit: 100 RPM)
R-Square .99945
(Limit: 0.97)

TORQUE:
Number 997
Slope .90935
(Limit: 0.77/0.83-1.03)
Y-Intercept .387
(Limit: +-15 Ft-lbs)
Std Error 6.8738
(Limit: 13% Max Eng Tq)
R-Square .94218
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .92891
(Limit: 0.87/0.89-1.03)
Y-Intercept -.480
(Limit: +-5 BHP)
Std Error 6.4428
(Limit: 8%)
R-Square .95185
(Limit: 0.91)

WORK:
Actual 8.471
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.262
% Difference -8.54%

Ford New Holland Engine, Retarded Injection Timing
HD-FTP, Hot Start 1

HD920109
30 NH358-117-92-89V 1
1B HS4R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 05/05/92 TIME: 10:39:02 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920109 Manufacturer: FORD
Test Date/Time: 4-23-92 15:20 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 29.01 "HG
Dry Bulb Temperature: 84.50 F
Absolute Humidity: 59.11 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 5.75
Exhaust+Bkg, Gms 30.67
Net, Gm/Bhp-Hr 3.219

CO (BAG):
Background, PPM 1.72
Exhaust+Bkg, Gms 39.79
Net, Gms/Bhp-Hr 4.44

NOX (INTEGRATED):
Background, PPM .50
Exhaust+Bkg, Gms 58.05
Net, Gms/Bhp-Hr 6.452

CO2 (BAG)
Background, PPM .029
Exhaust+Bkg, Gms 5198.57
Net, Gms/Bhp-Hr 546.7

PARTICULATE:
Secondary Tare, Gms .152335
Secondary Part, Gms .152722
Primary Tare, Gms .153151
Primary Part, Gms .161596
Total, Gms/Bhp-Hr 1.12

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.255
Lbs/Bhp-Hr .383
Lbs/Measured 3.969

BRAKE HORSEPOWER-HOUR: 8.497

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99921
(Limit: 0.97-1.03)
Y-Intercept 2.151
(Limit: +/-50 RPM)
Std Error 10.954
(Limit: 100 RPM)
R-Square .99956
(Limit: 0.97)

TORQUE:
Number 997
Slope .91148
(Limit: 0.77/0.83-1.03)
Y-Intercept .477
(Limit: +/-15 Ft-Lbs)
Std Error 6.7368
(Limit: 13% Max Eng Tq)
R-Square .94459
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .93353
(Limit: 0.87/0.89-1.03)
Y-Intercept -.524
(Limit: +/-5 BHP)
Std Error 6.0958
(Limit: 8%)
R-Square .95709
(Limit: 0.91)

WORK:
Actual 8.497
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.262
% Difference -8.26%

Ford New Holland Engine, Retarded Injection Timing
HD-FTP, Hot Start 2

HD920110
30 NH358-117-92-89V 1
1B CS3R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/24/92 TIME: 14:20:24 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920110 Manufacturer: FORD
Test Date/Time: 4-24-92 7:25 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 28.92 "HG
Dry Bulb Temperature: 82.70 F
Absolute Humidity: 55.21 Grains H2O/Lbs Dry Air

EMISSION RESULTS: CS

HC (INTEGRATED):
Background, PPM 3.94
Exhaust+Bkg, Gms 44.81
Net, Gm/Bhp-Hr 4.934

CO (BAG):
Background, PPM 1.72
Exhaust+Bkg, Gms 51.70
Net, Gms/Bhp-Hr 5.76

NOX (INTEGRATED):
Background, PPM 1.00
Exhaust+Bkg, Gms 67.90
Net, Gms/Bhp-Hr 7.280

CO2 (BAG)
Background, PPM .031
Exhaust+Bkg, Gms 5190.24
Net, Gms/Bhp-Hr 534.0

PARTICULATE:
Secondary Tare, Gms .154070
Secondary Part, Gms .154732
Primary Tare, Gms .152295
Primary Part, Gms .165760
Total, Gms/Bhp-Hr 1.71

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.272
Lbs/Bhp-Hr .380
Lbs/Measured 4.395

BRAKE HORSEPOWER-HOUR: 8.619

CYCLE STATISTICS: CS

SPEED:
Number 1175
Slope 1.00095
(Limit: 0.97-1.03)
Y-Intercept 2.721
(Limit: +-50 RPM)
Std Error 12.689
(Limit: 100 RPM)
R-Square .99941
(Limit: 0.97)

TORQUE:
Number 997
Slope .92307
(Limit: 0.77/0.83-1.03)
Y-Intercept .410
(Limit: +-15 Ft-Lbs)
Std Error 7.422%
(Limit: 13% Max Eng Tq)
R-Square .93506
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .93199
(Limit: 0.87/0.89-1.03)
Y-Intercept -.140
(Limit: +-5 BHP)
Std Error 6.998%
(Limit: 8%)
R-Square .94403
(Limit: 0.91)

WORK:
Actual 8.619
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.262
% Difference -6.94%

Ford New Holland Engine, Retarded Injection Timing
HD-FTP, Cold Start 2

HD920111
30 NH358-117-92-89V 1
1B HS5R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/24/92 TIME: 14:20:46 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920111 Manufacturer: FORD
Test Date/Time: 4-24-92 8: 4 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 28.94 *HG
Dry Bulb Temperature: 84.30 F
Absolute Humidity: 56.22 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 4.24
Exhaust+Bkg, Gms 32.58
Net, Gm/Bhp-Hr 3.545

CO (BAG):
Background, PPM 1.72
Exhaust+Bkg, Gms 40.48
Net, Gms/Bhp-Hr 4.52

NOX (INTEGRATED):
Background, PPM 1.50
Exhaust+Bkg, Gms 67.52
Net, Gms/Bhp-Hr 7.256

CO2 (BAG)
Background, PPM .033
Exhaust+Bkg, Gms 5025.88
Net, Gms/Bhp-Hr 518.6

PARTICULATE:
Secondary Tare, Gms .157922
Secondary Part, Gms .158327
Primary Tare, Gms .157217
Primary Part, Gms .166319
Total, Gms/Bhp-Hr 1.23

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.099
Lbs/Bhp-Hr .365
Lbs/Measured 4.040

BRAKE HORSEPOWER-HOUR: 8.494

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope 1.00031
(Limit: 0.97-1.03)
Y-Intercept 2.377
(Limit: +-50 RPM)
Std Error 11.135
(Limit: 100 RPM)
R-Square .99955
(Limit: 0.97)

TORQUE:
Number 997
Slope .90929
(Limit: 0.77/0.83-1.03)
Y-Intercept .768
(Limit: +-15 Ft-Lbs)
Std Error 6.701
(Limit: 13% Max Eng Tq)
R-Square .94488
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .93100
(Limit: 0.87/0.89-1.03)
Y-Intercept -.412
(Limit: +-5 BHP)
Std Error 6.024
(Limit: 8%)
R-Square .95783
(Limit: 0.91)

WORK:
Actual 8.494
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.262
% Difference -8.29%

Ford New Holland Engine, Retarded Injection Timing
HD-FTP, Hot Start 3

HD920112
30 NH358-117-92-89V 1
1B HS6R

HEAVY DUTY DIESEL TRANSIENT TEST

DATE: 04/24/92 TIME: 14:21:07 PAGE: 6

DIESEL SUMMARY REPORT

Test Number: HD-920112 Manufacturer: FORD
Test Date/Time: 4-24-92 8:44 Engine ID: 30 NH358-117-92-89V 1

AMBIENT DATA:

Barometer: 28.94 "HG
Dry Bulb Temperature: 84.10 F
Absolute Humidity: 57.72 Grains H2O/Lbs Dry Air

EMISSION RESULTS: HS

HC (INTEGRATED):
Background, PPM 4.24
Exhaust+Bkg, Gms 30.37
Net, Gm/Bhp-Hr 3.315

CO (BAG):
Background, PPM 1.72
Exhaust+Bkg, Gms 38.65
Net, Gms/Bhp-Hr 4.34

NOX (INTEGRATED):
Background, PPM 1.50
Exhaust+Bkg, Gms 60.17
Net, Gms/Bhp-Hr 6.511

CO2 (BAG)
Background, PPM .033
Exhaust+Bkg, Gms 5039.35
Net, Gms/Bhp-Hr 524.6

PARTICULATE:
Secondary Tare, Gms .158405
Secondary Part, Gms .158771
Primary Tare, Gms .157830
Primary Part, Gms .166567
Total, Gms/Bhp-Hr 1.17

FUEL CONSUMPTION:
Lbs/Carbon Balance 3.100
Lbs/Bhp-Hr .368
Lbs/Measured 4.040

BRAKE HORSEPOWER-HOUR: 8.420

CYCLE STATISTICS: HS

SPEED:
Number 1175
Slope .99968
(Limit: 0.97-1.03)
Y-Intercept 2.451
(Limit: +-50 RPM)
Std Error 12.042
(Limit: 100 RPM)
R-Square .99947
(Limit: 0.97)

TORQUE:
Number 997
Slope .90715
(Limit: 0.77/0.83-1.03)
Y-Intercept -.130
(Limit: +-15 Ft-Lbs)
Std Error 6.861
(Limit: 13% Max Eng Tq)
R-Square .94212
(Limit: 0.85/0.88)

POWER:
Number 997
Slope .92857
(Limit: 0.87/0.89-1.03)
Y-Intercept -.662
(Limit: +-5 BHP)
Std Error 6.409
(Limit: 8%)
R-Square .95228
(Limit: 0.91)

WORK:
Actual 8.420
(Limit: -15%-5% Ref Bhp-Hr)
Reference 9.262
Difference -9.09%

Ford New Holland Engine, Retarded Injection Timing
HD-FTP, Hot Start 4

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

Table E.1
John Deere 6068T Engine, Production Injection Timing,
Production Injectors 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 E.2
John Deere 6068T Engine, Production Injection Timing,
Production Injectors 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 E.3
John Deere 6068T Engine, Retarded Injection Timing,
Production Injectors 8-Mode Steady-State #1

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	2/19	1992						
Speed, rpm	2200	2200	2200	2200	1300	1300	1300	960
Torque, Ft-lb	320.0	241.0	161.5	37.0	476.0	356.0	260.0	5.0
Power, Hp	134.0	101.0	67.7	15.5	117.8	88.1	64.4	0.9
Water In, deg F	135.9	135.3	135.5	134.6	135.6	135.3	134.6	132.6
Water Out, deg F	164.2	162.9	161.9	160.2	164.2	164.5	162.2	156.9
Oil, deg F	210.0	208.1	206.4	203.1	199.8	205.1	195.5	189.8
Inlet Air, deg F	84.1	82.3	81.0	81.0	82.3	82.0	81.3	80.3
Fuel, deg F	75.3	78.2	81.3	82.0	83.4	81.3	81.7	80.6
Fuel Return, deg F	117.3	121.4	117.3	115.9	115.2	113.9	110.4	106.3
Exhaust, deg F	978.3	893.1	773.8	580.2	1054	955.1	812.2	385.5
Inlet Restriction in H2O	12.3	10.2	8.3	6.1	3.6	3.0	2.4	1.1
Exhaust Restriction in Hg	2.4	2.1	1.6	1.0	0.95	0.70	0.55	0.0
Fuel Flow, gal/hour	7.2	3.0	2.1	1.2	3.0	2.4	1.5	---
Sample Zone Temp, deg F	198.8	186.1	163.2	123.1	156.6	138.6	121.4	91.9
Filter Face Temp, deg F	110.8	134.9	132.3	114.5	122.4	118.6	107.7	97.4
Exhaust HC, ppm	21.16	20.11	28.99	248.44	13.13	17.56	14.41	16.81
Exhaust NO _x , ppm	145.6	92.2	55.8	20.2	171.1	107.5	78.0	9.7
Exhaust CO ₂ , %	0.990	1.025	0.802	0.375	1.135	0.830	0.608	0.105
Exhaust CO, ppm	201.6	170.1	75.3	147.1	82.7	17.7	119.6	18.3
Background HC, ppm	4.24	4.24	4.24	4.24	2.97	2.97	2.97	2.97
Background NO _x , ppm	3.85	3.85	3.85	3.85	3.85	3.85	3.85	3.85
Background CO ₂ , %	0.050	0.050	0.050	0.050	0.039	0.039	0.039	0.039
Background CO, ppm	2.50	2.50	2.50	2.50	0.63	0.63	0.63	0.63
Stabilization Time, min	5	5	5	5	5	5	5	5
Collection Time, min	5	5	5	5	5	10	15	20

Table E.4
John Deere 6068T Engine, Retarded Injection Timing,
Production Injectors 8-Mode Steady-State #2

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	2/26	1992						
Speed, rpm	2200	2200	2200	2200	1300	1300	1300	960
Torque, Ft-lb	320.5	244.0	163.5	32.0	475.0	352.0	243.5	0.0
Power, Hp	134.3	102.2	68.5	13.4	117.6	87.1	60.3	0.0
Water In, deg F	135.9	134.6	134.6	133.9	135.9	134.3	133.9	132.3
Water Out, deg F	164.9	163.9	162.2	159.5	164.9	164.2	162.0	157.2
Oil, deg F	209.8	211.8	207.8	200.4	201.8	206.4	197.5	188.1
Inlet Air, deg F	82.0	82.0	82.0	80.3	82.7	82.0	82.0	81.3
Fuel, deg F	80.0	80.3	81.3	82.0	83.0	81.0	81.3	81.3
Fuel Return, deg F	122.4	122.4	119.0	115.6	116.6	116.6	111.8	108.7
Exhaust, deg F	956.4	888.0	778.1	604.5	1069	972.0	771.2	398.1
Inlet Restriction in H2O	12.1	10.6	8.3	6.2	3.6	3.0	2.4	1.1
Exhaust Restriction in Hg	2.4	2.0	1.5	0.9	0.9	0.6	0.5	0.1
Fuel Flow, gal/hour	7.2	6.0	4.2	2.1	6.0	4.2	2.7	---
Sample Zone Temp, deg F	207.8	186.5	162.9	123.4	144.9	140.9	125.5	96.0
Filter Face Temp, deg F	129.6	134.6	125.2	113.2	121.7	119.3	114.2	100.8
Exhaust HC, ppm	22.59	20.49	29.21	251.5	14.56	18.08	16.21	17.41
Exhaust NO _x , ppm	155.0	96.6	56.8	14.9	175.3	108.8	66.8	5.9
Exhaust CO ₂ , %	1.240	0.995	0.795	0.367	1.122	0.827	0.569	0.103
Exhaust CO, ppm	239.2	166.4	76.0	141.9	80.0	15.7	10.1	13.8
Background HC, ppm	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69
Background NO _x , ppm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Background CO ₂ , %	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Background CO, ppm	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88
Stabilization Time, min	5	5	5	5	5	5	5	5
Collection Time, min	5	5	5	5	5	10	10	20

Table E.5
John Deere 6068T Engine, Retarded Injection Timing,
Modified Injectors 8-Mode Steady-State #1

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	3/9	1992						
Speed, rpm	2200	2200	2200	2200	1300	1300	1300	960
Torque, Ft-lb	331.5	250.2	165.5	37.0	485.0	364.0	245.0	3.0
Power, Hp	138.9	104.8	69.3	15.5	120.0	90.1	60.6	0.5
Water In, deg F	135.9	134.9	134.6	133.6	135.3	134.6	133.9	132.6
Water Out, deg F	165.2	164.9	163.2	162.2	167.2	163.9	133.6	153.6
Oil, deg F	213.8	212.4	208.4	204.1	206.1	205.4	197.8	185.5
Inlet Air, deg F	84.4	82.3	83.4	81.7	83.4	81.7	82.7	81.0
Fuel, deg F	82.0	83.7	84.7	84.7	85.4	83.0	83.0	82.3
Fuel Return, deg F	124.8	122.8	119.3	117.6	118.6	116.6	112.1	108.0
Exhaust, deg F	957.2	879.2	773.4	560.1	1083	957.2	758.1	344.0
Inlet Restriction in H2O	12.4	10.2	8.0	6.0	3.5	2.8	2.4	1.1
Exhaust Restriction in Hg	2.4	1.8	1.3	0.8	0.8	0.0	0.0	0.0
Fuel Flow, gal/hour	7.2	5.7	3.9	1.8	5.7	4.2	2.7	---
Sample Zone Temp, deg F	210.1	186.1	161.9	122.1	154.6	136.9	117.6	85.4
Filter Face Temp, deg F	120.4	116.6	112.8	105.3	118.6	115.6	108.0	92.6
Exhaust HC, ppm	12.16	11.19	16.66	280.2	8.79	11.41	12.23	15.68
Exhaust NO _x , ppm	179.3	110.3	62.8	17.1	194.7	132.3	79.0	4.9
Exhaust CO ₂ , %	1.015	0.870	0.734	0.348	1.099	0.760	0.536	0.091
Exhaust CO, ppm	159.6	106.9	51.3	144.9	101.3	15.2	7.7	13.7
Background HC, ppm	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87
Background NO _x , ppm	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Background CO ₂ , %	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
Background CO, ppm	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Stabilization Time, min	5	5	5	5	5	5	5	5
Collection Time, min	5	5	5	5	5	10	15	20

Table E.6
John Deere 6068T Engine, Retarded Injection Timing,
Modified Injectors 8-Mode Steady-State #2

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	3/11	1992						
Speed, rpm	2200	2200	2200	2200	1300	1300	1300	960
Torque, Ft-lb	331.5	251.0	166.0	34.0	485.0	365.1	242.0	3.0
Power, Hp	138.9	105.1	69.5	14.2	120.1	90.4	59.9	0.6
Water In, deg F	137.3	135.9	135.3	134.6	135.9	135.6	135.3	132.9
Water Out, deg F	165.9	163.5	163.5	161.2	154.2	154.2	154.2	157.2
Oil, deg F	205.8	211.1	208.8	203.1	203.4	202.8	193.1	191.1
Inlet Air, deg F	84.1	83.0	82.7	81.7	84.1	82.7	82.0	82.3
Fuel, deg F	70.4	73.6	76.4	79.2	81.3	80.0	80.0	80.0
Fuel Return, deg F	113.9	116.3	115.6	115.2	115.9	113.9	108.7	106.7
Exhaust, deg F	936.1	873.7	778.1	557.6	1074	937.4	724.5	371.9
Inlet Restriction in H2O	12.5	10.3	8.3	6.1	3.5	2.8	2.4	1.1
Exhaust Restriction in Hg	2.1	1.9	1.7	0.8	0.8	0.6	0.5	0.1
Fuel Flow, gal/hour	7.2	5.7	4.2	2.1	5.7	4.2	2.7	---
Sample Zone Temp, deg F	191.8	187.1	161.9	122.4	151.6	136.9	113.5	93.6
Filter Face Temp, deg F	105.0	116.3	114.9	106.0	111.1	108.4	99.8	94.3
Exhaust HC, ppm	11.78	10.74	16.21	228.0	9.02	10.14	10.14	12.61
Exhaust NO _x , ppm	185.5	112.5	65.5	17.7	199.7	130.5	79.8	8.2
Exhaust CO ₂ , %	1.222	0.939	0.751	0.350	1.097	0.767	0.538	0.097
Exhaust CO, ppm	186.9	118.9	53.3	125.3	91.0	15.5	7.7	12.0
Background HC, ppm	2.83	2.83	2.83	2.83	2.83	2.83	2.83	2.83
Background NO _x , ppm	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Background CO ₂ , %	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Background CO, ppm	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Stabilization Time, min	5	5	5	5	5	5	5	5
Collection Time, min	5	5	5	5	5	10	15	20

Table E.7
Ford New Holland Engine, Production Injection Timing
8-Mode Steady-State #1

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	4/3	1992						
Speed, rpm	2100	2100	2100	2100	1260	1260	1260	875
Torque, Ft-lb	322.0	242.7	164.0	34.5	380.0	287.9	192.4	4.5
Power, Hp	128.8	97.0	65.6	13.8	91.2	69.1	46.2	0.8
Water In, deg F	137.9	136.9	136.9	136.3	137.9	136.3	136.3	138.9
Water Out, deg F	167.2	163.9	161.5	158.2	165.2	161.9	159.9	158.2
Oil, deg F	197.2	199.8	191.9	182.3	174.9	174.9	167.1	150.1
Inlet Air, deg F	83.7	83.0	82.3	82.7	85.4	85.1	84.1	85.1
Fuel, deg F	61.8	60.8	60.8	65.7	66.1	67.5	68.9	68.9
Fuel Return, deg F	82.0	82.3	81.7	79.6	78.2	78.5	75.7	77.8
Exhaust, deg F	1273	997.0	772.1	504.0	1185	919.1	689.7	290.5
Inlet Restriction in H2O	12.2	12.1	12.2	12.7	4.7	4.9	5.0	2.55
Exhaust Restriction in Hg	4.4	3.8	3.2	2.4	2.2	1.4	1.1	0.4
Fuel Flow, gal/hour	7.2	4.8	3.6	1.8	4.8	3.3	2.1	0.3
Sample Zone Temp, deg F	182.2	164.9	146.2	122.1	123.4	124.1	112.1	90.9
Filter Face Temp, deg F	118.0	120.0	114.5	107.7	109.1	108.0	103.6	92.6
Exhaust HC, ppm	8.13	34.19	46.00	66.53	13.79	27.63	31.28	19.32
Exhaust NO _x , ppm	200.2	155.0	100.6	28.1	127.6	117.9	74.8	11.0
Exhaust CO ₂ , %	1.048	0.884	0.643	0.215	1.311	0.601	0.412	0.105
Exhaust CO, ppm	359.1	59.9	27.9	35.6	298.4	23.4	15.1	13.2
Background HC, ppm	3.59	3.59	3.59	3.59	3.59	3.59	3.59	3.59
Background NO _x , ppm	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Background CO ₂ , %	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Background CO, ppm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stabilization Time, min	5	5	5	5	5	5	5	5
Collection Time, min	5	5	10	5	5	10	10	20

Table E.8
Ford New Holland Engine, Production Injection Timing
8-Mode Steady-State #2

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	4/9	1992						
Speed, rpm	2100	2100	2100	2097	1260	1260	1260	890
Torque, Ft-lb	326.0	245.6	163.5	34.0	385.5	290.5	193.5	3.0
Power, Hp	130.4	98.2	65.4	13.6	92.5	69.7	46.4	0.5
Water In, deg F	138.3	137.6	137.3	137.3	137.9	137.6	137.6	136.3
Water Out, deg F	168.9	164.9	162.5	159.9	165.5	162.2	159.9	136.3
Oil, deg F	216.4	216.1	211.8	197.1	190.1	189.0	180.2	164.9
Inlet Air, deg F	84.1	82.7	81.7	82.0	85.4	84.1	83.4	84.7
Fuel, deg F	68.9	68.9	68.9	68.9	68.9	70.4	70.7	70.4
Fuel Return, deg F	85.1	86.5	87.5	88.9	89.9	88.5	87.1	88.2
Exhaust, deg F	1276	985.5	768.7	476.9	1188	901.9	674.3	281.1
Inlet Restriction in H2O	12.2	12.5	12.9	13.2	4.8	4.8	5.0	2.6
Exhaust Restriction in Hg	4.4	3.8	3.4	2.5	2.1	1.4	1.2	0.4
Fuel Flow, gal/hour	7.2	5.1	3.6	1.8	4.8	3.3	2.1	0.3
Sample Zone Temp, deg F	187.8	162.2	138.6	112.1	132.9	119.0	106.7	83.7
Filter Face Temp, deg F	109.4	126.2	118.3	106.3	111.5	109.1	102.9	91.9
Exhaust HC, ppm	9.16	32.47	45.25	63.43	13.20	26.36	30.98	22.21
Exhaust NO _x , ppm	201.2	152.6	122.9	25.5	128.6	116.5	72.8	9.7
Exhaust CO ₂ , %	0.811	0.762	0.649	0.225	0.848	0.587	0.433	0.096
Exhaust CO, ppm	268.3	49.3	24.7	37.6	431.0	17.7	17.3	14.4
Background HC, ppm	4.76	4.76	4.76	4.76	4.76	4.76	4.76	4.76
Background NO _x , ppm	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06
Background CO ₂ , %	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
Background CO, ppm	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03
Stabilization Time, min	5	5	5	5	5	5	5	5
Collection Time, min	5	5	10	5	5	10	10	20

Table E.9
Ford New Holland Engine, Retarded Injection Timing
8-Mode Steady-State #1

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	4/20	1992						
Speed, rpm	2100	2100	2100	2100	1260	1260	1260	890
Torque, Ft-lb	328.0	250.0	164.0	41.0	386.0	292.0	198.0	5.5
Power, Hp	131.2	100.0	65.6	16.4	92.6	70.1	47.5	0.9
Water In, deg F	137.9	137.6	137.3	136.6	137.9	137.6	137.3	135.9
Water Out, deg F	176.5	172.7	169.9	166.5	172.5	169.9	166.5	162.5
Oil, deg F	209.4	206.4	198.5	188.5	176.5	176.2	165.5	149.9
Inlet Air, deg F	88.5	87.5	86.8	87.1	89.2	88.2	87.5	89.2
Fuel, deg F	66.4	67.2	67.5	67.9	67.9	68.6	69.6	68.9
Fuel Return, deg F	83.7	83.4	84.1	83.7	82.7	82.7	79.6	79.2
Exhaust, deg F	1357	1041	807.1	532.5	1240	964.0	707.3	275.8
Inlet Restriction in H2O	4.9	4.1	3.6	2.8	2.0	1.7	1.2	0.4
Exhaust Restriction in Hg	12.2	12.4	12.8	13.1	4.8	4.8	5.0	2.6
Fuel Flow, gal/hour	7.5	5.1	3.6	1.8	4.8	3.3	4.5	---
Sample Zone Temp, deg F	195.5	165.5	143.9	114.1	131.9	120.0	107.3	83.0
Filter Face Temp, deg F	120.0	132.6	121.1	109.1	112.8	109.7	104.3	93.3
Exhaust HC, ppm	7.76	34.57	50.56	300.1	11.88	27.63	33.97	32.47
Exhaust NO _x , ppm	128.3	101.8	69.3	15.6	95.2	76.3	52.8	10.8
Exhaust CO ₂ , %	1.068	0.683	0.699	0.238	0.827	0.601	0.448	0.096
Exhaust CO, ppm	270.9	57.9	40.2	158.9	303.7	17.7	22.7	20.8
Background HC, ppm	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73
Background NO _x , ppm	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Background CO ₂ , %	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Background CO, ppm	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Stabilization Time, min	5	5	5	5	5	5	5	5
Collection Time, min	5	5	10	5	5	10	10	20

Table E.10
Ford New Holland Engine, Retarded Injection Timing
8-Mode Steady-State #2

Measurement	Mode							
	1	2	3	4	5	6	7	8
Date	4/21	1992						
Speed, rpm	2100	2100	2100	2100	1260	1260	1260	890
Torque, Ft-lb	328.5	249.0	165.6	37.6	386.0	290.2	194.0	5.0
Power, Hp	131.4	99.6	66.2	15.0	92.6	69.6	46.5	0.8
Water In, deg F	137.9	136.9	136.9	136.3	138.6	136.6	136.9	136.3
Water Out, deg F	176.8	172.2	169.5	166.5	172.5	168.9	166.5	162.9
Oil, deg F	209.8	205.8	196.1	188.5	175.5	176.8	169.5	148.6
Inlet Air, deg F	89.9	88.5	87.1	87.1	89.5	90.2	89.2	89.5
Fuel, deg F	68.6	68.9	68.9	68.9	68.9	69.3	70.0	69.6
Fuel Return, deg F	85.8	84.7	84.1	84.7	84.1	86.1	85.1	85.7
Exhaust, deg F	1366	1045	797.4	524.2	1230	963.1	716.7	273.5
Inlet Restriction in H2O	5.0	4.0	3.4	2.7	2.1	1.6	1.3	0.4
Exhaust Restriction in Hg	12.1	12.5	12.8	13.0	4.8	4.8	5.0	2.6
Fuel Flow, gal/hour	7.2	5.1	3.6	1.8	5.1	3.3	2.1	0.3
Sample Zone Temp, deg F	196.8	167.5	144.2	115.6	133.6	122.1	109.1	82.7
Filter Face Temp, deg F	117.3	133.9	111.8	108.0	106.3	106.3	102.2	89.9
Exhaust HC, ppm	9.38	35.61	48.50	300.1	13.42	26.74	32.10	28.00
Exhaust NO _x , ppm	123.6	103.1	68.8	12.8	89.2	70.0	47.0	3.3
Exhaust CO ₂ , %	1.068	0.788	0.495	0.314	0.813	0.542	0.336	0.098
Exhaust CO, ppm	287.1	63.9	46.7	163.4	306.3	20.2	24.0	20.8
Background HC, ppm	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22
Background NO _x , ppm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Background CO ₂ , %	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Background CO, ppm	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Stabilization Time, min	5	5	5	5	5	5	5	5
Collection Time, min	5	5	5	5	5	5	5	5