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EVALUATION OF FPC-1® FUEL PERFORMANCE CATALYST

AT

JACK B. PARSONS COMPANIES

REPORT PREPARED BY
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PROVO, UTAH

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INTRODUCTION

FPC-1® is a complex combustion catalyst that, when added to liquid hydrocarbon fuels in minute proportions (1:5000), improves the combustion reaction, resulting in increased engine thermal efficiency and reduced fuel consumption.

Field and laboratory tests alike indicate a potential to reduce fuel consumption in diesel fleets in the range of 4% to 9%. These same tests also indicate FPC-1® fuel treatment reduces smoke and other harmful emissions (CO, HC, NOx). This report summarizes the results of controlled back-to-back chassis dynamometer tests conducted in cooperation with Jack B. Parsons Companies and ICM, with and without FPC-1® added to the fuel.

TEST METHODS

Two methods of fuel consumption determination were used. With each truck mounted on the heavy duty diesel chassis dynamometer at ICM, fuel consumption changes were calculated using a direct measurement of vehicle brake specific fuel consumption (vbsfc).
Also, under the same engine conditions, exhaust emissions were analyzed for carbon mass flow rate (carbon balance fuel consumption) determination.

ENGINES TESTED

The following engine makes were tested:
4 x L10 Cummins

TEST EQUIPMENT

The equipment and instruments involved in the carbon balance test were:

A Sun Electric SGA-9000 non-dispersive, infrared analyzer (NDIR) for measuring the exhaust gas constituents, HC (unburned hydrocarbons as hexane gas), CO, CO2, and O2. The SGA-9000 is EPA approved for emissions analysis.

A Fluke Model 51 type k thermometer and thermocouple for measuring exhaust gas, ambient, and fuel temperature.

A Dwyer Magnehelic and pitot tube for exhaust pressure determination.

A hydrometer and flask for fuel specific gravity determination.

A Hewlett Packard Model 41C programmable calculator for the calculation of the engine performance factors and vbsfc changes.

TEST PROCEDURE

Carbon Balance

The carbon balance technique for determining changes in fuel consumption has been recognized by the US Environment Protection Agency (EPA) since 1973, and is central to the EPA standardized Federal Test Procedures and Highway Fuel Economy Tests. The method relies upon the measurement of engine exhaust emissions to determine fuel consumption rather than direct measurement (volumetric or gravimetric) of fuel consumption.

The carbon balance method produces a value of engine fuel consumption with FPC-1® relative to a baseline value established with the same vehicle.

Engine emissions were taken with each truck mounted and running on a heavy duty diesel chassis dynamometer at a specific engine speed and load. Each vehicle was run on the dyno at 1300, 1500, 1700, 1900, and 2100 rpm.

Specific Fuel Consumption

Measurement of vbsfc is also well recognized. It is a direct measurement of fuel consumed per unit of horsepower produced. The dynamometer monitors horsepower to the wheels, torque, engine speed (rpm) and fuel consumption.

Engine speed and load are duplicated from test to test, and measurements of exhaust and ambient temperature are made. Three trucks were first tested with base fuel. After a FPC-1® treated fuel engine conditioning period of approximately 300 hours, the trucks were tested again while running on FPC-1® treated base fuel. A fourth truck was used as a control, and was not treated with FPC-1®.

The three baseline/treated trucks were equipped with a heat exchanger. Comparisons were made between baseline and treated data from trucks with the heat exchanger operating only, with the exception of the control (Unit 161) which was never heat exchanger equipped.

Table 1 summarizes the results of the specific fuel consumption test (vbsfc). Table 2 summarizes the carbon mass balance results. The carbon mass balance calculations and raw data sheets are found in the Appendices.

Table 1.

Specific Fuel Consumption

Fleet VBSFC (Base)	Fleet VBSFC (FPC-1®)	%Improvement
0.5695	0.5172	+ 9.18%

Table 2.

Carbon Mass Balance

Unit No.	Engine	RPM	%Improvement
163 (w/exchanger)	L10 Cummins	1300-2100	+ 16.35
163 (w/exchanger)	L10 Cummins	1300-2100	+ 7.30
169 (w/exchanger)	L10 Cummins	1300-2100	+ 2.10
112 (w/exchanger)	L10 Cummins	1300-2100	+ 4.25
161 (wo/exchanger)	L10 Cummins	1300-2100	+ 0.77 Control

The general trend of improved (reduced) fuel consumption is similar to that documented in several EPA and SAE tests.

DISCUSSION AND CONCLUSION

The average reduction in vbsfc is 9.18% with FPC-1® treated fuel. The control (Unit 161) experienced a 3.24% improvement in vbsfc without FPC-1® fuel treatment. If it is assumed that the control represents a change in the baseline for the entire fleet, the improvement in FPC-1® treated vbsfc would be 5.94%.

The average reduction in fuel consumption with FPC-1® treatment using carbon mass balance is 7.50%. Again, the control demonstrated an improvement without FPC-1® fuel treatment (0.77%). If this change is considered significant, the adjusted fuel economy improvement would then be 6.73%.

The improvements in fuel economy were accompanied by reductions in smoke opacity using an accel erator peddle "snap test", a reduction in carbon monoxide of 4%, and a reduction in unburned hydro carbons of 26.15%.

APPENDICES

CARBON BALANCE METHOD TECHNICAL APPROACH:

A fleet of L10 Cummins diesel powered ready mix trucks was selected for the FPC-1® evaluation. The SGA-9000 exhaust gas analyzer, the thermometer, and the pressure gauge were calibrated prior to the baseline and treated fuel test runs. The SGA-9000 was calibrated using Scott Calibration Gases(I/M Protocol Gases). A leak and a low flow check of the sampling hose and connections was performed.

Each engine was stabilized at the specific rpm and operating temperature as indicated by the engine water, oil, and exhaust temperature, and exhaust pressure. No exhaust gas measurements were taken until each engine had stabilized at the engine speed selected for the test.

Number 2 Diesel fuel was used exclusively throughout the test. Fuel specific gravity (density) and temperature were determined from the rolling tank on each truck at the beginning of each chassis dyno run.

The baseline fuel consumption test consisted of five sets of measurements of CO_2, CO, unburned hy drocarbons (measured as CH_4), O_2, exhaust temperature and pressure. Each engine was tested in the same manner.

After the baseline test, on January 20, 1992, the fuel storage tanks, from which the fleet was exclu sively fueled, was treated with FPC-1® at the recommended concentration of 1 oz. of catalyst to 40 gallons of diesel fuel (1:5000 volume ratio). The equipment was then operated with the treated fuel as normal until March 4, 1992, when the treated fuel test was run. At this time, the test described above was repeated for each engine, only this time with FPC-1® treated fuel.

Throughout the entire fuel consumption test, technicians calibrated the exhaust analyzer every 90 sec onds to correct instrument drift, if any.

Using the exhaust gas measurements, the average molecular weight (Mwt) of the gases can be calcu lated, and an engine performance factor (pf) determined based upon changes in the carbon (fuel) containing exhaust gases, principally carbon dioxide (CO2), in the exhaust stream. The temperature and pressure differential of the exhaust stream, the barometric pressure, and the fuel specific gravity of the fuel can then be used to correct for changes in the engine performance factor that might be related to exhaust air volume, ambient conditions, or fuel density. The final engine performance factor (PF) relates the fuel consumption of the treated fuel to the baseline. The basic formula for the calculation of the Mwt, pf, and PF are found in Figure 1. Figure2 contains a sample calculation.

EXHAUST GAS SUMMARY

COMPANY: JBP — UNIT NO.: 163

EQUIPMENT: OSH KOSH READY MIX TRUCK

ENGINE MAKE: CUMMINS — MODEL: L10

FUEL: D2

BASELINE — DATE: 1-20-92

ENGINE MILES (HRS): 24841 (2438) — OPACITY: 63% (snap test)

ENGINE SPEED: 1300 - 2100 RPM

AIR TEMPERATURE: 49.8 deg F

BAROMETRIC: 25.5

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	11.05	8.74	8.24	7.60	6.62	8.45
CO%	0.09	0.03	0.03	0.03	0.03	0.042
O2%	4.10	7.50	8.50	9.20	10.70	8.00
HCppm	10.00	8.00	9.00	10.0	10.0	9.40
EXHAUST TEMP. (F)	764.0	810.6	791.8	773.8	757.8	779.6
EXH Pv (H20)	3.6	4.8	6.2	7.6	7.0	5.84

TREATED — DATE: 3-4-92

ENGINE MILES (HRS): 27691 (2645) — OPACITY:

ENGINE SPEED: 1300 - 2100 RPM

AIR TEMPERATURE: 59.2 deg F

BAROMETRIC: 25.5

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	11.41	9.60	8.51	7.86	7.51	8.98
CO%	0.13	0.04	0.03	0.02	0.03	0.05
O2%	4.70	6.90	8.90	9.50	9.90	7.98
HCppm	5.00	5.00	9.00	10.0	8.00	7.40
EXHAUST TEMP. (F)	876.4	842.4	799.0	783.4	762.8	812.8
EXH Pv (H2O)	2.2	3.0	4.0	4.9	5.6	3.94

EXHAUST GAS SUMMARY

COMPANY: JBP — UNIT NO.: 163

EQUIPMENT: OSH KOSH READY MIX TRUCK

ENGINE MAKE: CUMMINS — MODEL: L10

FUEL: D2

BASELINE — DATE: 1-20-92

ENGINE MILES (HRS): 24841 (2438) — OPACITY:

ENGINE SPEED: 1300 - 2100 RPM

AIR TEMPERATURE: 68.6 deg F

BAROMETRIC: 25.5

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	11.57	9.73	8.81	8.09	7.74	9.18
CO%	0.17	0.05	0.03	0.03	0.03	0.062
O2%	3.70	6.00	7.00	7.90	8.20	6.56
HCppm	5.00	8.00	6.00	6.00	8.00	6.60
EXHAUST TEMP. (F)	853.8	845.0	813.4	790.6	781.2	816.8
EXH Pv (H20)	2.6	4.2	5.2	6.8	7.4	5.24

TREATED — DATE: 3-4-92

ENGINE MILES (HRS): 27691 (2645)

ENGINE SPEED: 1300 - 2100 RPM

AIR TEMPERATURE: 59.2 deg F

BAROMETRIC: 25.5

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	11.41	9.60	8.51	7.86	7.51	8.98
CO%	0.13	0.04	0.03	0.02	0.03	0.05
O2%	4.70	6.90	8.90	9.50	9.90	7.98
HCppm	5.00	5.00	9.00	10.0	8.00	7.40
EXHAUST TEMP. (F)	876.4	842.4	799.0	783.4	762.8	812.8
EXH Pv (H2O)	2.2	3.0	4.0	4.9	5.6	3.94

EXHAUST GAS SUMMARY
COMPANY: JBP — UNIT NO.: 163
EQUIPMENT: OSH KOSH READY MIX TRUCK
ENGINE MAKE: CUMMINS — MODEL: L10
FUEL: D2

BASELINE — DATE: 1-20-92

ENGINE MILES (HRS): 24841 (2438) — OPACITY: 53%
ENGINE SPEED: 1300 - 2100 RPM
AIR TEMPERATURE: 68.6 deg F
BAROMETRIC: 25.5

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	10.80	9.30	8.30	7.60	7.20	8.64
CO%	0.14	0.05	0.03	0.02	0.02	0.052
O2%	4.90	6.80	8.50	9.30	10.0	7.90
HCppm	5.00	6.00	5.00	5.00	7.00	5.60
EXHAUST TEMP. (F)	858.0	843.0	809.0	784.8	77.02	813.2
EXH Pv (H20)	2.8	3.8	4.8	5.8	7.2	4.88

TREATED — DATE: 3-4-92

ENGINE MILES (HRS): 27691 (2645)
ENGINE SPEED: 1300 - 2100 RPM
AIR TEMPERATURE: 59.2 deg F
BAROMETRIC: 25.5

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	11.41	9.60	8.51	7.86	7.51	8.98
CO%	0.13	0.04	0.03	0.02	0.03	0.05
O2%	4.70	6.90	8.90	9.50	9.90	7.98
HCppm	5.00	5.00	9.00	10.0	8.00	7.40
EXHAUST TEMP. (F)	876.4	842.4	799.0	783.4	762.8	812.8
EXH Pv (H2O)	2.2	3.0	4.0	4.9	5.6	3.94

EXHAUST GAS SUMMARY

COMPANY: JBP UNIT NO.: 169
EQUIPMENT: OSH KOSH READY MIX TRUCK
ENGINE MAKE: CUMMINS MODEL: L10
FUEL: D2

BASELINE DATE: 1-20-92

ENGINE MILES (HRS): 21492 (2529) OPACITY: 58%
ENGINE SPEED: 1300 - 2100 RPM
AIR TEMPERATURE: 57.4 deg F
BAROMETRIC: 25.5

TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.	
CO2%	12.10	10.3	8.90	8.10	7.90	9.46
CO%	0.24	0.07	0.03	0.02	0.02	0.076
O2%	2.70	4.80	7.50	8.30	8.50	6.36
HCppm	4.00	5.00	10.0	10.0	15.0	8.80
EXHAUST TEMP. (F)	844.2	872.2	785.8	778.2	753.6	806.8
EXH Pv (H20)	1.8	2.8	3.6	4.6	5.8	3.72

TREATED DATE: 3-4-92

ENGINE MILES (HRS): 23363 (2650) OPACITY: 60%
ENGINE SPEED: 1300 - 2100 RPM
AIR TEMPERATURE: 63.8 deg F
BAROMETRIC: 25.5

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	11.24	9.40	8.89	8.08	7.44	9.01
CO%	0.13	0.04	0.02	0.02	0.02	0.046
O2%	5.30	7.10	7.80	8.90	9.60	7.74
HCppm	5.00	4.00	5.00	6.00	6.00	5.20
EXHAUST TEMP. (F)	820.0	831.2	787.0	767.4	741.4	789.4
EXH Pv (H2O)	2.0	3.1	4.2	4.8	5.4	3.90

EXHAUST GAS SUMMARY
COMPANY: JBP UNIT NO.: 112

EQUIPMENT: OSH KOSH READY MIX TRUCK
ENGINE MAKE: CUMMINS — MODEL: L10
FUEL: D2

BASELINE — DATE: 1-20-92

ENGINE MILES (HRS): 25052 (3385) — OPACITY: 81%
ENGINE SPEED: 1300 - 2100 RPM
AIR TEMPERATURE: 38.4 deg F
BAROMETRIC: 25.5

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	9.00	9.10	8.20	7.70	7.40	8.28
CO%	0.04	0.04	0.02	0.02	0.02	0.028
O2%	7.50	7.30	9.00	9.80	8.60	8.44
HCppm	0.00	6.00	9.00	12.0	12.0	9.75
EXHAUST TEMP. (F)	824.0	832.6	807.6	762.6	761.0	797.6
EXH Pv (H20)	(1.8)	3.6	5.6	6.0	7.2	4.84

TREATED — DATE: 3-4-92

ENGINE MILES (HRS): 25540 (3566) — OPACITY: 41%
ENGINE SPEED: 1300 - 2100 RPM
AIR TEMPERATURE: 57.8 deg F
BAROMETRIC: 25.5

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	11.73	9.28	8.63	7.61	7.29	8.90
CO%	0.16	0.04	0.03	0.02	0.02	0.054
O2%	4.60	7.20	8.00	9.20	9.70	7.74
HCppm	2.00	6.00	5.00	6.00	7.00	5.20
EXHAUST TEMP. (F)	847.4	818.2	786.8	780.6	774.2	801.44
EXH Pv (H2O)	1.8	3.0	4.2	4.9	5.2	3.82

EXHAUST GAS SUMMARY

COMPANY: JBP — UNIT NO.: 161

EQUIPMENT: OSH KOSH READY MIX TRUCK

ENGINE MAKE: CUMMINS — MODEL: L10

FUEL: D2

BASELINE 1 — DATE: 1-20-92

ENGINE MILES (HRS): 25843 (3147) — OPACITY: 51%

ENGINE SPEED: 1300 - 2100 RPM

AIR TEMPERATURE: 49.8 deg F

BAROMETRIC: 25.5

. . . .	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	10.46	9.05	8.35	7.97	7.08	8.58
CO%	0.07	0.04	0.03	0.03	0.02	0.038
O2%	6.70	8.90	9.70	10.5	11.5	9.46
HCppm	4.00	5.00	2.00	6.00	2.00	3.80
EXHAUST TEMP. (F)	819.0	781.0	761.6	759.0	728.8	769.9
EXH Pv (H20)	2.8	3.8	4.6	5.6	6.0	4.56

BASELINE 2 — DATE: 3-4-92

ENGINE MILES (HRS): 30635 (3339) — OPACITY: 39%

ENGINE SPEED: 1300 - 2100 RPM

AIR TEMPERATURE: 62.2 deg F

BAROMETRIC: 25.5

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	11.42	9.60	8.61	8.10	7.41	9.03
CO%	0.16	0.05	0.04	0.03	0.03	0.062
O2%	4.40	6.80	8.20	8.60	9.30	7.46
HCppm	5.00	6.00	6.00	6.00	8.00	6.20
EXHAUST TEMP. (F)	860.0	825.4	805.2	763.8	764.2	803.7
EXH Pv (H2O)	2.2	3.2	4.2	4.9	6.2	4.14

Figure 2.

SAMPLE CALCULATION FOR THE CARBON MASS BALANCE

Baseline:

Equation 1 Volume Fractions

VFCO2	= 1.932/100
	= 0.01932
VFO2	= 18.95/100
	= 0.1895
VFHC	= 9.75/1,000,000
	= 0.00000975
VFCO	= 0.02/100
	= 0.0002

Equation 2 Molecular Weight

$$Mwt1 = (0.00000975)(86) + (0.0002)(28) + (0.01932)(44) + (0.1895)(32) + [(1 - 0.00000975 - 0.0002 - 0.1895 - 0.01932)(28)]$$

$$Mwt1 = 29.0677$$

Equation 3 Calculated Performance Factor

$$pf1 = \frac{2952.3 \times 29.0677}{86(0.00000975) + 13.89(0.0002) + 13.89(0.01932)}$$

pf1 = 316,000 (rounded to nearest meaningful place)

Treated:

Equation 1 Volume Fractions

$$VFCO2 = 1.832/100 = 0.01832$$

$$VFO2 = 18.16/100 = 0.1816$$

$$VFHC = 10.2/1{,}000{,}000 = 0.0000102$$

$$VFCO = .02/100 = 0.0002$$

Equation 2 Molecular Weight

$$Mwt2 = (0.0000102)(86)+(0.0002)(28)+(0.01832)(44)+(0.1816)(32) +[(1-0.0000102-0.0002-0.1816-0.01832)(28)]$$

$$Mwt2 = 29.0201$$

Equation 3 Calculated Performance Factor

$$pf2 = \frac{2952.3 \times 29.0201}{86(0.0000102)+13.89(0.0002)+13.89(0.01832)}$$

$$pf2 = 332{,}000 \text{ (rounded)}$$

Equation 4 Percent Change over Baseline in Engine Performance:

$$\%\text{ Change E.P.} = [(332{,}000 - 316{,}000)/316{,}000](100)$$

$$= + 4.8\%$$

A 4.8% improvement in engine performance equates to a 4.8% reduction in fuel consumption.

Table 1

Calculation of Fuel Consumption Changes

Unit No. 163/1300 - 2100 RPM (with Heat Exchanger)

Mwt1	29.6725	Mwt2	29.7532
pf1	74,217.360	pf2	69,997.7851
PF1	42,049.4874	PF2	48,925.7064

% Change E. P. = [(48,925 - 42,049)/42,049](100)

= + 16.35%

Table 2

Unit No. 163/1300 - 2100 RPM (with Heat Exchanger)

Mwt1	29.6987	Mwt2	29.7532
pf1	72,594.399	pf2	69,997.7851
PF2	45,599.7390	PF2	48,925.7064

% Change E.P. = [(48,925 - 45,599)/45,599}](100)

= + 7.3%

Table 3

Unit No. 169/1300 - 2100 RPM (with Heat Exchanger)

Mwt1	29.7685	Mwt2	29.7515
pf1	66,313.3598	pf2	69,803.3626
PF1	47,588.7638	PF2	48,586.5011

% Change E.P. = [(48,586 - 47,588)/47,588](100)
= + 2.10%