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INTRODUCTION

FPC-1 is a combustion catalyst which, when added to liquid hydrocarbon fuels at a ratio of 1:5000, improves the combustion reaction resulting in increased engine 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 8%.

FPC-1 was first tested by Occidental Chemical Company at the Florida Operations in two D9N dozers. After 440 hours of FPC-1 use, the dozers rate of fuel consumption decreased from 13.72 gallons per hour (gph) to 12.50 gph. This reflects a percentage improvement in fuel economy of 8.9%.

Subsequently, Occidental Chemical managers expanded the test to a fleet of three scrapers, one grader, and a tractor. For a period of ten weeks, the fleet baseline fuel consumption numbers were tabulated. During this time period, the three scrapers averaged 15.45 gph, the grader 9.3 gph, and the tractor 10.14 gph.

The above fleet was then run on FPC-1 treated fuel 200 to 300 hours. During the treated fuel period, the scraper rate of fuel consumption decreased to 14.32 gph, the grader rate of fuel use decreased to 8.9 gph, and the tractor rate of fuel consumption to 7.7 gph. The decreased rate of fuel consumption demonstrated by the test fleet while using FPC-1 treated diesel represents an 11.89% improvement in fuel economy.

The average fuel savings for the seven units tested (dozers, scrapers, grader, and tractor) was 8.71%

Subsequent to the above field tests in diesel equipment, Occidental Chemical managers chose to test FPC1 in a fleet of gasoline powered pickup trucks. This report summarizes the results of controlled back-to-back field tests conducted at the Florida Operation, with and without FPC-1 added to the fuel. The test procedure applied was the Carbon Balance Exhaust Emission Tests at a given engine load and speed.

EQUIPMENT TESTED:

The following equipment were tested:

7 gasoline powered pickup trucks

TEST INSTRUMENTS:

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

Sun Electric SGA-9000 non-dispersive, infrared analyzer (NDIR) for measuring the exhaust gas constituents, HC (unburned hydrocarbons as hexane gas), CO, CO_2 and O_2.

Scott Specialty BAR 90 calibration gases for SGA-9000 internal calibration.

A Fluke Model 51 type k thermometer and wet/dry probe for measuring exhaust, fuel, and ambient temperature.

A Dwyer Magnehelic and pitot tube for exhaust pressure differential measurement and exhaust air flow determination (CFM).

A hand held photo tachometer for engine speed (rpm) determination where dash mounted tachometers are not available.

A hydrometer for fuel specific gravity (density) measurement.

A Hewlett Packard Model 42S programmable calculator for the calculation of the engine performance factors.

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- Federal Test Procedures (FTP) and Highway Fuel Economy Test (HFET). The method relies upon the measurement of vehicle exhaust emissions to determine fuel consumption rather than direct measurement (volumetric or gravimetric) of fuel consumption.

The application of the carbon balance test method utilized in this study involves the measurement of exhaust gases of a stationary vehicle under steady-state engine conditions. The method produces a value of engine fuel consumption with FPC-1 relative to a baseline value established with the same vehicle.

Engine speed and load are duplicated from test to test, and measurements of carbon containing exhaust gases (CO2, CO, HC), oxygen (O2), exhaust and ambient temperature, and exhaust and ambient pressure are made. A minimum of five readings are taken for each of the above parameters after engine stabilization has taken place (rpm, and exhaust, oil, and water temperature have stabilized). The technical approach to the carbon balance method is detailed in Appendix 1.

Fuel density is measured enabling corrections to be made to the final engine performance factors based upon the energy content of the fuel reaching the injectors. A significant change in fuel density (measured as its specific gravity) can lead to inaccuracies in the test results, unless corrected for.

Seven pieces of equipment were tested for both baseline and treated fuel segments. Table 1 below summarizes the percent change in fuel consumption documented with the carbon balance on an individual basis.

Table 1: Summary of Carbon Balance Fuel Consumption Changes

Unit	Engine	RPM	%Change Fuel Consumed
151	CAT 3306	1690 `	- 11.60
153	CAT3408	1050	+ 0.67
832	CAT3408	1030	- 9.74
023	CAT3306	1300	- 15.18
024	PERKINS	2275	- 12.88
022			
830	PERKINS	2260	- 2.06

DISUCSSION

1) Changes in CO and HC

FPC-1 fuel treatment had a positive effect upon CO. Carbon monoxide (CO) was reduced approximately 60 parts per million or 11.7%. Five of the six units tested experienced reductions in CO.

HC emissions increased during the FPC-1 treated fuel test. The NDIR test instrument (SUN SGA-9000) measures HC as hexane gas, a hydrocarbon that is produced in very small concentrations in diesel engines. This gas tends to increase slightly after initial FPC-1 treatment, however, laboratory tests at recognized independent laboratories such as Southwest Research Institute and Systems Control, Inc., verify FPC-1 has no negative effect upon HC emissions once full engine conditioning has taken place The increase in HC (fleet average of 4 parts per million) may indicate engine conditioning is not complete or may be related to a change in fuel properties. In Any case, the increase in hexane gas was only 4 parts per million.

2) Exhaust Odor and Smoke

Exhaust odor (due to unburned fuel) was less noticeable with FPC-1 treatment. Smoke density was visibly reduced. The smoke density test indicated half of the fleet was producing less smoke on FPC-1 treated fuel. The other half remained unchanged. The smoke density test is done while the engines are running at a fixed rpm, but under no load. Although unavoidable, this test condition tends to minimize the smoke density change created by FPC-1 fuel treatment It was apparent that the engines smoked less when under load.

CONCLUSIONS

1) The fuel consumption change determined by the carbon balance method for the fleet, ranges from + 0.67% to – 15.18%. The fleet average reduction in fuel consumed is approximately 8.5%.

2) Unburned hydrocarbons (HC) increased 4 parts per million, while carbon monoxide (CO) was reduced 11.7% after FPC-1 treatment.

3) Diesel odor and visible smoke were reduced after FPC-1 treatment. The smoke density test confirmed an improving trend in smoke density.

APPENDICES

Appendix 1

CARBON BALANCE METHOD TECHINICAL APPROACH:

A fleet of diesel powered construction equipment owned and operated b BOISE CASCADE CORPORATION was selected for the FPC-1 field test. The fleet was made up of 3 loaders, 2 Hysters, and a

All test instruments were calibrated and zeroed prior to both baseline and treated fuel data collection . The SGA-9000 NDIR exhaust gas analyzer was internally calibrated using Scott Calibration Gases (BAR 90 Gases), and a leak test on the sampling hose and connections was performed.

Each vehicle's engine was brought up to operating temperature at a set rpm and allowed to stabilize as indicated by the engine water, oil, and exhaust temperature and exhaust pressure. No exhaust gas measurements were made until each engine had stabilized at the rpm selected for the test. Unleaded fuel was exclusively used for the diesel fleet throughout the evaluation. Fuel specific gravity and temperature were taken before testing.

The baseline fuel consumption test consisted of a minimum of five sets of measurements of CO2, CO, HC, O2 and exhaust temperature and pressure made at 90 second intervals. Each engine was tested in the same manner. Rpm and intake air temperature were also recorded at approximately 90 second intervals.

After the baseline test, the fuel storage tanks were treated with FPC-1 at the recommended level of 1 oz. of catalyst to 40 gallons of fuel (1:5000 volume ratio). Additional fuel supplied to cascade after the baseline was also treated.

Throughout the baseline and treated test measurement process, an internal self-calibration of the exhaust analyzer was performed after every two sets of measurements to correct instrument drift, if any.

From the exhaust gas concentrations measured during the test, the molecular weight of each constituent, and the temperature and density of the exhaust stream, the fuel consumption may be expressed as a "performance factor" which relates the fuel consumption of the treated fuel to the baseline. The calculations are based on the assumption that engine operating conditions are essentially the same throughout the test. Engines with known mechanical problems or having undergone repairs affecting fuel consumption are removed from the sample.

A sample calculation is found in Figure 2. All performance factors are rounded off to the nearest meaningful place in the sample.

Table 2 Summary of Emissions Data

	Base Fuel				FPC-1 Fuel			
Unit#	CO	HC	CO2	RPM	CO	HC	CO2	RPM
5116	.030	18.8	4.59	1692	.027	24.5	4.35	1964
5124	.040	7.3	3.74	1048	.030	8.4	3.50	1044
5120	.050	10.0	3.68	1029	.054	12.6	4.01	1029
5114	.040	13.8	3.07	1315	.030	11.6	2.65	1326
5824	.070	19.9	2.92	2256	.060	33.7	3.07	2257

Table 3. Summary of Ambient Conditions

	Ave. Air Temperature	Barometric Pressure
Baseline	54.0 Deg F	26.945
Treated	74.8 Deg F	27.076

Table 4. Fuel Density (specific gravity) Comparison

	Base Fuel SG	Treated Fuel SG	Correction Factor
Diesel	.850	.845	1.0059

Table 5. Calculation of Fuel Consumption Changes

5116/1690 RPM

Mwt1	29.3315	Mwt2	29.3094
pf1	134,604	pf2	141,836
PF1	205,223	PF2	227,776

227,776 (1.0059) = 229,120

% Change PF = [(229,120 – 205,223)/205,223](100)

*** Change PF = + 11.6%**

Table 6

5124/1050 RPM

Mwt1	29.2428	Mwt2	29.2073
pf1	164,235	pf2	175,604
PF1	132,520	PF2	130,856

130,856(1.0059) = 131,628

%Change PF = [(131,628 – 132,520)/132,520](100)

****Change PF = - 0.67%**

*A positive change in PF equates to a reduction in fuel consumption.

** A negative change in PF equates to an increase in fuel consumption, however this change is so small that it is insignificant.

Table 7

5115/1315 RPM

Mwt1	29.1680	Mwt2	29.1127
Pf1	198,798	pf2	230,273
PF1	350,217	PF2	401,030

401,030 (1.0059) = 403,396

% Change PF = [(403,396 – 350,217)/350,217](100)

% Change PF = +15.18%

Table 8

5120/1030 RPM

Mwt1	29.2414	Mwt2	29.2503
Pf1	166,352	pf2	152,687
PF1	117,757	PF2	128,467

128,467 (1.0059) = 129,225

% Change PF = [(129,227 – 117,757)/117,757](100)

%Change PF = 9.74%

Table 9

5824/2275 RPM

Mwt1	29.1520	Mwt2	29.1322
Pf1	204,667	pf2	211,806
PF1	412,490	PF2	462,890

462,890 (1.0059) = 465,621

% Change PF = [(465,621 – 412,490/412,490](100)

***% Change PF = +12.88%**

*A positive change in PF equates to a reduction in fuel consumption.

Table 10

5825/2260 RPM

Mwt1	29.1524	Mwt2	29.1452
Pf2	206,383	Pf2	196,605
PF2	502,215	PF2	509,548

509,548 (1.0059) = 512,554

%Change PF = [(512,554 – 502,515)/502,515](100)

%Change PF = +2.06%

Figure 1
CARBON MASS BALANCE FORUMULA

ASSUMPTIONS: C_8H_{15} and SG = 0.78
Time is constant
Load is constant

DATA:

Mwt = Molecular Weight
Pf1 = Calculated Performance Factor (Baseline)
Pf2 = Calculated Performance Factor (Treated)
PF1 = Performance Factor (adjusted for Baseline exhaust mass)
PF2 = Performance Factor (adjusted for Treated exhaust mass)
T = Temperature ^{o}F
F = Flow (exhaust CFM)
SG = Specific Gravity
VF = Volume Fraction

VFCO2 = "reading" ÷ 100
VFO2 = "reading" ÷ 100
VFHC = "reading" ÷ 1,000,000
VFCO = "reading" ÷ 100

EQUATIONS:

$$Mwt = (VFHC)(86)+(VFCO)(28)+(VFCO2)(44)+(VFO2)(32)+[(1-VFHC-VFCO-VFO2-VFCO2)(28)]$$

$$Pf1 \text{ or } pf2 = \frac{2952.3 \times Mwt}{89(VFHC)+13.89(VFCO)+13.89(VFCO2)}$$

$$PF1 \text{ or } PF2 \quad \frac{pf \times (T+460)}{F}$$

FUEL ECONOMY:
PERCENT INCREASE (OR DECREASE) $\frac{PF2 - PF1}{PF1} \times 100$

Figure 2.

SAMPLE CALCULATION FOR TH ECARBON MASS BALANCE

<u>Baseline:</u>

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 = 00.02/100
= 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)