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EVALUATION OF FPC-1® FUEL PERFORMANCE CATALYST

AT

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Smoky Canyon Mine

REPORT PREPARED BY
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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 5% to 9%. This report summarizes the results of controlled back-to-back field tests conducted at the Simplot Company, Smoky Canyon Mine, 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 was tested:

3 x Cat 785 Haul Trucks with 3512 engines
2 x Cat 16G Patrols with 3406 engines

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, CO2, and O2.

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 the Appendices.

Fuel specific gravity or 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. Exhaust smoke density was also measured to determine the effect of FPC-1® on this product of incomplete combustion. The change in smoke density is not used in the carbon balance calculation.

Five pieces of mining equipment were tested for both baseline and treated fuel segments. Table 1 below summarizes the percent change in fuel consumption based upon the change in carbon mass in the exhaust. Table 2 summarizes the percent change in fuel consumption when corrected for ambient conditions.

Table 1:

Summary of Carbon Balance Fuel Consumption Changes
(Carbon Mass Change in the Exhaust)

Unit	Engine	RPM	% Change Fuel Consumption
*88	CAT 3512	1800	- 7.70
92	CAT 3512	1800	-12.23
P91	CAT 3512	1800	- 9.75
P10	CAT 3406	1800	- 9.57
P12	CAT 3406	1800	+ 0.05

* The PT injection system was replaced with an electronic system one week before the treated test segment.

Table 2:

Summary of Carbon Balance Fuel Consumption Changes
(Corrected for Changes in Ambient Conditions)

Unit	Engine	RPM	% Change Fuel Consumption
*88	CAT 3512	1800	- 9.56
92	CAT 3512	1800	-12.62
91	CAT 3512	1800	-10.53
P10	CAT 3406	1800	-11.01
P12	CAT 3406	1800	- 0.25

* The PT injection system was replaced with an electronic system one week before the treated test segment.

DISCUSSION

1. Change in Exhaust Smoke Density

Smoke was reduced in four of the five engine tested while using FPC-1® treated fuel. Smoke density on a fleet average was reduced 14.53%. This is consistent with the observations of mechanics and operators who have commented on a less dense, lighter colored smoke since FPC-1 treatment.

These data agree with the observations of the testing technicians. The smoke being emitted from the engines was less profuse and lighter in color than observed during the baseline fuel test. Table 3 in the Appendices summarizes the changes in smoke density.

2. Fuel Density

Fuel specific gravity (density) for the baseline and treated tests are found on Table 4, along with the correction factors applied to the final engine performance factors (PF). Fuel being consumed by the fleet during the FPC-1® treated test was more dense and, therefore, contained more energy. The increased energy content is not related to the use of FPC-1, but is likely due to seasonal changes in fuel quality.

3. Emissions Changes

Baseline CO and HC emissions were low, averaging .032% and 11.5 part per million (ppm), respectively. However, although produced in lower concentrations that usually encountered in off-road heavy duty diesel engines, FPC-1® had an impact upon these products of incomplete combustion. CO was reduced from in the one unit producing high CO levels. HC was reduced in all engines tested. Table 5 summarizes the emissions data.

Also, exhaust odor created by unburned fuel in the exhaust was less noticeable with FPC-1® treatment.

4. Effect of Ambient Conditions

Average air temperature was in the mid-60s for both tests. Barometric pressure for the two test segments did change dramatically averaging 29.68 " Hg for the baseline and 30.10 " Hg for the treated test segment. These data were used to correct engine parameters to standard conditions. Therefore, ambient conditions were corrected for and had little impact upon the fuel consumption changes. The mathematics for the carbon balance, including the corrections for ambient conditions are found on Figure 1 in the Appendices. A sample calculation is also found in the Appendices on Figure 2.

5. Exhaust Pressure Readings

Unlike emissions of carbon containing exhaust gases (CO2, CO, HC,) and smoke, exhaust pressure readings are difficult to measure and to accurately reproduce. Air flow rates across the opening of the exhaust can vary significantly, causing inaccuracies in the adjustments having to do with exhaust density.

Additionally, even the most precise and practical instruments available have increments of measurement large enough to create some inaccuracies. It is for this reason, based upon years of testing experience, that small changes in exhaust pressure are considered identical from test to test, especially if engine rpm and exhaust temperature are nearly identical.
Exhaust pressures were within the accuracy limits of the instruments used and, therefore were considered identical for the purposes of this test. Consequently, exhaust pressures were considered unchanged in the final calculation of the performance factors shown on Table 2 above.

CONCLUSIONS

1) The fuel consumption change determined by the carbon balance method based upon carbon change in the exhaust only ranged from + 0.05% to -12.23%. The fleet averaged a 7.84% reduction in fuel consumed.

2) The fuel consumption change when the carbon mass in the exhaust is corrected for ambient conditions ranged from - 0.25% to - 12.62%, with a fleet average reduction in fuel usage of 8.79%.

3) Unburned hydrocarbons were reduced 18% after FPC-1® treatment. CO was reduced in the unit producing high CO levels (Unit P12). All other units produced very low CO levels (0.02%), and were unaffected by FPC-1 treatment.

3) Smoke density was reduced 14.53% after FPC-1® fuel treatment, which is consistent with observation of Smoky Canyon personnel, as well as the testing technicians.

APPENDICES

Appendix 1

CARBON BALANCE METHOD TECHNICAL APPROACH:

A fleet of diesel powered mining equipment owned and operated by the Simplot Company, Smoky Canyon Mine was selected for the FPC-1® field test. The fleet was made of three 785 haul trucks and two 16G graders.

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. # 2 Diesel fuel was exclusively used 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 CO_2, CO, HC, O_2, and exhaust temperature and pressure made at 90 second intervals. Each engine was tested in the same manner. Rpm, exhaust temperature, exhaust pressure, 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 diesel fuel (1:5000 volume ratio). Each succeeding fuel shipment was also treated with FPC-1®. The equipment was operated on treated fuel until the final test was run.

During the two test segments, 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 3:

Smoke Density Comparison

Unit	Base Smoke #	FPC-1® Treated Smoke #	% Change
88	6.75	5.75	-14.81
92	6.00	5.50	- 8.33
91	5.00	5.00	00.00
P10	7.75	6.50	-16.13
P12	5.25	3.50	-33.33

Table 4:

Fuel Density (specific gravity) Comparison

Base Fuel SG	Treated Fuel SG	Correction Factor
.830	.834	.9952

Table 5:

Summary of Emissions Data

	Base Fuel				FPC-1® Fuel			
Unit #	CO%	HC	CO2%	RPM	CO%	HC	CO2%	RPM
88	.020	11.5	2.600	1800	.020	10.2	2.392	1800
92	.030	12.5	2.910	1800	.030	10.0	2.572	1800
91	.030	13.6	2.790	1800	.030	11.2	2.510	1800
P10	.020	4.8	2.740	1800	.020	3.5	2.480	1800
P12	.060	15.0	2.087	1800	.050	12.2	2.083	1800
FLEET AVE.	**.032**	**11.5**	**2.625**	**1800**	**.030**	**9.4**	**2.407**	**1800**
% CHANGE FROM BASE FUEL:					**6.25%**	**18.3%**	**8.30%**	**nc**

Table 6:
Summary of Ambient Conditions

	Ave. Air Temperature	Barometric Pressure
Baseline	65.20 deg F	29.68
Treated	67.30 deg F	30.10

Carbon Balance Calculation of Fuel Consumption Changes

Table 7
88/1800 RPM

Mwt1	29.0907	Mwt2	28.9793
pf1	235,360	pf2	254,703
PF1	98,349	PF2	108,273

108,273 (.9952) = 107,753

% Change PF = [(107,753 - 98,349)/98,349](100)
***% Change PF = + 9.56%**

Table 8
91/1800 RPM

Mwt1	29.1235	Mwt2	29.0022
pf1	219,477	pf2	242,031
PF1	84,305	PF2	93,663

93,663(.9952) = 93,184

% Change PF = [(93,184 - 84,305)/84,305}](100)
***% Change PF = + 10.53%**

Table 9
92/1800 RPM

Mwt1	29.1134	Mwt2	29.0201
pf1	209,712	pf2	236,493
PF1	80,620	PF2	91,229

91,229(.9952) = 90,791

% Change PF = [(90,791 - 80,620)/80,629](100)
***% Change PF = + 12.62**

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

Table 10
P10/1800 RPM

Mwt1	29.1059	Mwt2	29.0194
pf1	223,903	pf2	246,508
PF1	222,916	PF2	248,644

248,644(.9952) = 247,451

% Change PF = [(247,451 - 222,916)/222,916](100)

***% Change PF = + 11.01%**

Table 11
P12/1800 RPM

Mwt1	29.0380	Mwt2	28.9512
pf1	286,232	pf2	287,474
PF1	243,089	PF2	244,880

244,880(.9952) = 243,705

% Change PF = [(243,705 - 243,089)/243,089}](100)

***% Change PF = + 0.25%**

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

Figure 1
CARBON MASS BALANCE FORMULA

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

DATA:

Mwt	=	Molecular Weight
pf_1	=	Calculated Performance Factor (Baseline)
pf_2	=	Calculated Performance Factor (Treated)
PF_1	=	Performance Factor (adjusted for Baseline exhaust mass)
PF_2	=	Performance Factor (adjusted for Treated exhaust mass)
T	=	Temperature (°F)
F	=	Flow (exhaust CFM)
SG	=	Specific Gravity
VF	=	Volume Fraction

$VFCO_2$ = "reading" ÷ 100
VFO_2 = "reading" ÷ 100
VFHC = "reading" ÷ 1,000,000
VFCO = "reading" ÷ 100

EQUATIONS:

$$\text{Mwt} = (\text{VFHC})(86)+(\text{VFCO})(28)+(\text{VFCO}_2)(44)+(\text{VFO}_2)(32)+[(1-\text{VFHC}-\text{VFCO}-\text{VFO}_2-\text{VFCO}_2)(28)]$$

$$pf_1 \text{ or } pf_2 = \frac{2952.3 \times \text{Mwt}}{89(\text{VFHC})+13.89(\text{VFCO})+13.89(\text{VFCO}_2)}$$

$$PF_1 \text{ or } PF_2 = \frac{pf \times (T+460)}{F}$$

FUEL ECONOMY:
PERCENT INCREASE (OR DECREASE)

$$\frac{PF_2 - PF_1}{PF_1} \times 100$$

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 in Engine Performance Factor:

$$\% \text{ Change PF} = [(332{,}000 - 316{,}000)/316{,}000](100) = +4.8\%$$

A + 4.8% change in the calculated engine performance factor equates to a 4.8% reduction in fuel consumption.