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EVALUATION OF FPC-1® FUEL PERFORMANCE CATALYST

AT

UTAH POWER AND LIGHT/SCENIC S.W. AREA CEDAR CITY, UTAH

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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® has been tested by This report summarizes the results of controlled back-to-back field tests conducted by UTAH POWER & LIGHT, SCENIC SOUTHWEST AREA, Cedar City, Utah, 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 engines were tested:

2 x 350 Gasoline
3 x 3208 CAT Diesels
1 x 8.2 Detroit Diesel

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 (CO_2, CO, HC), oxygen (O_2), 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 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.

Six 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 unit basis.

Table 1:
Summary of Carbon Balance Fuel Consumption Changes

Unit	Engine	RPM	% Change Fuel Consumed
3895	Detroit 3895	2000	- 7.82
4275	CAT 3208	2000	- 7.77
4444	CAT 3208	2000	- 2.20
3430	CAT 3208	2000	-10.70
*5100		2000	+ 1.70
*4750	GMC 350	1960	-14.10

* Gasoline powered trucks (see Discussion)

DISCUSSION

1) Gasoline Powered Trucks

The exhaust emissions data from the two gasoline trucks were unstable during both the baseline and treated fuel carbon balance test runs. The averages of the data indicate a positive change in fuel consumption with FPC-1® fuel treatment, however, the dramatic changes from data point to data point make it the results from the tests of these two trucks inconclusive. The inconsistent data may are probably responsible for the large difference in the percentage change in fuel consumption seen in the gasoline fleet (+1.7% and -14.1%).

2) Diesel Powered Trucks

The test data from the four diesel powered trucks are stable and the results fall into a reasonable grouping (-2.2% to -10.7%). Also, the density of the diesel fuel used in the test is known and was used to correct for the rate of fuel consumption based upon the energy content of the fuel reaching the injectors.

3) Changes in CO and HC

FPC-1® fuel treatment had a positive effect upon the products of incomplete combustion, CO and HC, in the diesel fleet. HC was reduced 3.1%; CO was reduced 27.5%.

Conversely, the gasoline FPC-1® treated fuel CO and HC emissions increased dramatically. Fuel density from test to test is unknown, and as mentioned above under subtitle 1, the emissions data from the gasoline fleet were erratic for both the baseline and treated fuel tests. Exhaust temperatures also changed rapidly. Since FPC-1® has been proven in sophisticated laboratory tests (Southwest Research Institute and Systems Control, Inc.) to have no harmful effect upon the products of combustion, it is likely the increases in CO and HC are a result of the inconsistent data, engine instability manifested in rapidly changing engine temperatures, and/or changes in fuel characteristics.

4) Exhaust Odor and Smoke

Exhaust odor (due to unburned fuel) was less noticeable with FPC-1® treatment. Several of the exhaust stacks on the diesel trucks are underneath and at the center of the truck. Consequently, the exhaust is partially trapped under the truck body for a period of time.
The technician doing the exhaust sampling found it necessary to use a creeper to get under the truck and reach the exhaust stacks with the sampling probes.

During the baseline fuel test segment, the exhaust was rich with fuel and visible smoke, and had a heavy diesel odor that was irritating to the eyes and sinuses. During the FPC-1® treated test, the exhaust plume was cleaner. There was little visible smoke and the exhaust gases, with one exception (the 8.2 liter Detroit), did not irritate the eyes and sinuses of the technician.

CONCLUSIONS

1) The fuel consumption change determined by the carbon balance method for the fleet, including the two gasoline trucks (possibly anomalies) ranges from + 1.70% to -14.1%. The fleet average reduction in fuel consumed is approximately 6.73%.

2) The fuel consumption change for the fleet with the two gasoline powered trucks removed from the sample because of erratic data ranges from - 2.2% to -10.7%. The fleet average, in this case, is 7.12%.

3) Unburned hydrocarbons (HC) were directionally improved in the diesel fleet, while carbon monoxide (CO) was reduced 27.5% after FPC-1® treatment.

4) Diesel odor, visible smoke, and irritating fumes in the exhaust were reduced after FPC-1® treatment.

APPENDICES

CARBON BALANCE METHOD TECHNICAL APPROACH:

A fleet of diesel and gasoline powered utility equipment owned and operated by the Scenic Southwest Area of Utah Power & Light Company, was selected for the FPC-1® field test. The fleet was made up of four diesel power line trucks and two gasoline power pickups.

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, with the exception of the gasoline power vehicles whose data deviated dramatically. # 2 Diesel fuel was exclusively used for the diesel fleet throughout the evaluation. Both diesel and gasoline were supplied from the fuel storage tanks at the Cedar City location. 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 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 Utah Power & Light 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
3895	.060	19.2	1.604	2000	.052	29.8	1.530	1800
4275	.090	24.2	1.806	2000	.068	22.2	1.754	2000
4444	.094	30.8	1.554	2000	.070	28.4	1.540	2000
3430	.110	35.6	1.814	2000	.070	26.0	1.670	2000
*4750	1.13	33.8	12.21	1962	1.69	51.8	11.11	1959
*5100	2.17	56.2	12.06	2000	2.92	89.8	11.73	2000

* The two gasoline power pickups saw large deviations in emissions. The engines appeared to be cycling.

Table 3
Summary of Ambient Conditions

	Ave. Air Temperature	Barometric Pressure
Baseline	66.4 deg F	29.84
Treated	85.6 deg F	30.04

Table 4
Fuel Density (specific gravity) Comparison

	Base Fuel SG	Treated Fuel SG	Correction Factor
Diesel	.866	.852	1.0162

Calculation of Fuel Consumption Changes

Table 5

3430/2000 RPM

Mwt1	28.9923	Mwt2	28.9498
pf1	316,657	pf2	342,994
PF1	507,451	PF2	552,750

552,750 (1.0162) = 561,705

% Change PF = [(561,708 - 507,451)/507,451](100)

***% Change PF = + 10.69%**

Table 6

4444/2000 RPM

Mwt1	28.9720	Mwt2	28.9437
pf1	369,388	pf2	378,445
PF1	656,973	PF2	660,576

660,576 (1.0162) = 671,204

% Change PF = [(671,204 - 656,973)/656,973](100)

***% Change PF = + 2.22%**

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

Table 7

4275/2000 RPM

Mwt1	28.9928	Mwt2	28.9595
pf1	322,471	pf2	335,303
PF1	299,615	PF2	317,758

317,758 (1.0162) = 322,906

% Change PF = [(322,906 - 299,615)/299,615](100)

***% Change PF = + 7.77%**

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

Table 8

3895/2000 RPM

Mwt1	29.0090	Mwt2	28.9409
pf1	367,913	pf2	384,351
PF1	381,235	PF2	404,489

404,489 (1.0162) = 411,042

% Change PF = [(411,042 - 381,235)/381,235](100)

***% Change PF = + 7.82%**

Table 9

4750/1960 RPM

Mwt1	30.0296	Mwt2	29.7918
pf1	47,778	pf2	49,3478
PF1	933,243	PF2	1,064,696

% Change PF = [(1,064,696 - 933,243)/933,243](100)

***% Change PF = + 14.10%**

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

Table 10

5100/2000 RPM

Mwt1	29.9955	Mwt2	29.8820
pf1	44,634	pf2	43,198
PF1	1,240,204	PF2	1,219,167

% Change PF = [(1,219,167 - 1,240,204)/1,240,204](100)

***% Change PF = - 1.70%**

* As negative change in PF equates to an increase 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 (^{O}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:

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

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

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

FUEL ECONOMY:
PERCENT INCREASE (OR DECREASE)

$$\frac{PF_2 - PF_1}{PF_1} \text{ x } 100$$

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.