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EVALUATION OF FPC-1® FUEL PERFORMANCE CATALYST

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 10%. This report summarizes the results of controlled back-to-back field tests conducted at Memphis Cablevision, Memphis, TN., with and without FPC-1® added to the gasoline. 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:

- 1 x Ford Explorer
- 1 x Ford Escort
- 1 x Ford Econoline
- 1 x Ford Pickup
- 1 x Dodge Mini Van

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 of the SGA-9000.

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 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.

Five pieces of equipment were tested for both baseline and treated fuel segments. Table 1 below summarizes the percent change in fuel consumption.

Table 1: Summary of Carbon Balance Fuel Consumption Changes

Unit	Engine	RPM	% Change Fuel Consumption
12	Ford	2400	- 2.68
103	Ford	2500	- 9.81
114	Ford	3500	- 6.47
148	Ford	2500	- 9.21
202	Dodge	2400	-11.79

DISCUSSION

1. Drift in CO2 Readings

The SGA-9000 is a non-dispersive infrared (NDIR) analyzer approved by the EPA, and used by UHI and Diesel Ceramics to measure the concentrations of exhaust gases emitted by the test engines. The instrument is routinely calibrated, both at the beginning and ending of each test segment. Any drift in the calibration settings is noted in the test logbook or on the data sheets and corrections are made to the actual readings.

During the baseline, a calibration drift of an absolute -.12% in CO2 was noted. This is well within the range (1 to 3%) prescribed by SUN Electric and is typical for most emissions tests. During the treated fuel test, the drift was an absolute -1.20%, an abnormal drift for this instrument. The drift was probably a calibration inaccuracy occurring with the beginning calibration. The error was discovered in the final calibration at the end of the test, and recorded in the test logbook for correction purposes.

The negative absolute change in CO2 was added to the average of the treated CO2 readings as shown on Table 3 in the appendices and at the bottom of the raw data sheets attached. All engine performance calculations use the corrected CO2 readings. The correction actually reduced the degree of fuel consumption improvement with FPC-1 treated gasoline.

2. Fuel Density

Fuel specific gravity (density) for the baseline and treated tests are found on Table 3, along with the correction factors applied to the final engine performance factors (PF). Fuel being consumed during the FPC-1® treated test was less dense and, therefore, contained less energy. The correction factor corrects fuel consumption to that of the baseline fuel on a fuel density basis only, after the effect of FPC-1 is taken into consideration in the calculation.

3. Emissions Changes

Baseline CO and HC emissions were very low, and indicative of good catalytic converter efficiency. FPC-1® fuel treatment still had a significant impact upon HC and CO, creating a 32% reduction in HC and completely eliminating CO emissions.

4. Effect of Ambient Conditions

Average air temperature was in the high 40s for both the base and treated fuel tests. Barometric pressure for the base fuel test averaged 29.675 inches of mercury ("Hg). Barometric pressure averaged 29.646 "Hg for the treated fuel test. In both cases, the skies were overcast and there was rainfall.

These data were used to correct engine performance to standard conditions. Therefore, ambient conditions were corrected for and had little impact upon the fuel consumption changes. The equations 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.

CONCLUSIONS

1) The fuel consumption change determined by the carbon balance method ranged from a - 2.68% to -11.79%. The fleet averaged a 8.02% reduction in fuel consumed.

2) Unburned hydrocarbons (HC) and carbon monoxide (CO) emissions were extremely low during base fuel testing, typical of catalytic converter equipped engines. However, emissions of HC were reduced 32% (tailpipe out) after FPC-1® treatment. CO was completely eliminated after FPC-1® treatment.

APPENDICES

CARBON BALANCE METHOD TECHNICAL APPROACH:

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. The same procedure was repeated after each test segment to determine any instrument drift.

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. Premium unleaded gasoline 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 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 2: Fuel Density (specific gravity) Comparison

Base Fuel SG	Treated Fuel SG	*PF Corr. Factor
.746	.740	1.0080

* The correction factor for fuel density is used to correct the final engine performance factor (PF) for changes in fuel energy content, and therefore, fuel consumption.

Table 3: Summary of Emissions Data

	Base Fuel				FPC-1® Fuel			
Unit #	CO%	HC	CO2%	RPM	CO%	HC	CO2%	RPM
12	.007	2.00	* 8.55	2380	.000	2.00	* 7.94	2480
103	.010	2.83	*15.13	2500	.000	2.00	*12.37	2500
114	.010	3.70	*15.32	3490	.000	0.40	*13.50	3627
148	.007	2.00	*15.36	2500	.000	2.00	*13.48	2500
202	.005	3.00	*15.10	2400	.000	2.80	*12.47	2400
FLEET AVE.	**.0078**	**2.71**	**13.89**	**2654**	**.000**	**1.84**	**11.95**	**2701**
% Change from Base Fuel:					**-100**	**-32.1**	**-13.97**	**+1.77**

* Corrected for drift in calibration for CO2 analyzer.

Table 4: Summary of Barometric Pressure Readings

Base Ave.	29.675 "Hg
Treated Ave.	29.646 "Hg

Tables 5-9: Carbon Balance Calculation of Fuel Consumption Changes

Table 5: Unit 12

Mwt1	29.7844	Mwt2	29.6388
pf1	73,997	pf2	79,309
PF1	1,407,620	PF2	1,433,922

1,433,922(1.0080)= 1,445,393

% Change PF = [(1,445,393-1,407,620)/1,407,620](100)

***% Change PF = + 2.68%**

Table 6: Unit 103

Mwt1	30.5374	Mwt2	29.9969
pf1	42,858	pf2	51,537
PF1	1,251,331	PF2	1,363,176

1,363,175(1.0080)= 1,374,081

% Change PF = [(1,374,081-1,251,331)/1,251,331](100)

***% Change PF = + 9.81%**

Table 7: Unit 114

Mwt1	30.5871	Mwt2	30.2172
pf1	42,394	pf2	47,556
PF1	1,777,827	PF2	1,877,561

1,877,561(1.0080)= 1,892,581

% Change PF = [(1,892,581-1,777,827)/1,777,827](100)

***% Change PF = + 6.45%**

Table 8: Unit 148

Mwt1	30.5608	Mwt2	30.2009
pf1	42,274	pf2	47,615
PF1	1,302,694	PF2	1,413,592

1,413,592(1.0080)= 1,424,901

% Change PF = [(1,424,901-1,302,694)/1,302,694](100)

***% Change PF = + 9.38%**

Table 9: Unit 202

Mwt1	30.5693	Mwt2	30.0463
pf1	43,004	pf2	51,222
PF1	1,244,145	PF2	1,379,767

1,379,767(1.0080)= 1,390,805

% Change PF = [(1,390,805-1,244,145)/1,244,145](100)

***% Change PF = +11.79%**

* A positive change in PF equates to a similar 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 (^{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:

$$Mwt = (VFHC)(86)+(VFCO)(28)+(VFCO_2)(44)+(VFO_2)(32)+[(1-VFHC-VFCO-VFO_2-VFCO_2)(28)]$$

$$pf_1 \text{ or } pf_2 = \frac{2952.3 \times Mwt}{89(VFHC)+13.89(VFCO)+13.89(VFCO_2)}$$

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

FUEL ECONOMY:
PERCENT INCREASE (OR DECREASE)

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

Figure 2. Appendix 4

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)

Equation 4 Corrected Performance Factor

$$PF1 = \frac{316{,}000\ (357\ \text{deg F} + 460)}{850\ \text{cfm}}$$

PF1 = 304,000 (rounded)

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 (rounded)

Equation 4 Corrected Performance Factor

$$PF2 = \frac{332{,}000\ (357\ \text{deg F} + 460)}{850\ \text{cfm}}$$

PF2 = 319,000 (rounded)

Equation 5 Percent Change in Engine Performance Factor:

% Change PF = [(319,000 - 304,000)/304,000](100)

= *+ 4.9%

* Equates to a 4.9% reduction in fuel consumption.

Appendix 5

Raw Data Sheets