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EVALUATION OF FPC-1 FUEL PERFORMANCE CATALYST

AT

GREYHOUND LINES, INC.
SAN FRANCISCO, CALIFORNIA

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INTRODUCTION

FPC-1® is a complex combustion catalyst which, when added to liquid hydrocarbon fuels at a ratio of 1:5000, effectively improves the combustion reaction, resulting in increased engine efficiency and reduced fuel consumption.

Field and laboratory tests both indicate a potential to reduce fuel consumption in diesel fleets in the range of 4% to 8%. This report summarizes the results of controlled back-to-back field tests conducted in cooperation with Greyhound Lines, Inc., San Francisco, California, with and without FPC-1® added to the fuel. The test procedure applied was the Carbon Balance Exhaust Emission Test at a given load and engine speed.

ENGINES TESTED

The following engine makes were tested:

Bus Number	Engine Make
9034	6V92 DT
9015	6V92 DT
9058	6V92 DT
9012	6V92 DT
8975	6V92 DT
8981	6V92 DT
8940	6V92 DT
8985	6V92 DT
7040	6V92 DT
7010	6V92 DT
7031	6V92 DT
7007	6V92 DT
7003	6V92 DT

TEST EQUIPMENT

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.

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

A Dwyer magnehelic and pitot tube for exhaust pressure differential measurement.

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 41C programmable calculator for the calculation of the engine performance factors.

TEST PROCEDURES

Carbon Balance

The carbon balance technique for determining changes in fuel consumption has been recognized by the US Environment Protection Agency (EPA) since 1973. 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 fuel consumption test method utilized in this study involves the measurement of exhaust gases of a stationary vehicle at a steady engine load and rpm. 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 exhaust and ambient temperature are made. Under these conditions a minimum of five readings were taken for each parameter after stabilization of the exhaust temperature.

Thirteen busses were used for baseline and trated fuel comparison. Table 1 summarizes the results on an individual bus basis. Table 2 summarizes the change in fuel consumption a\on an individual bus basis.

CONCLUSIONS

The carbon balance emission tests conducted on a number of Detroit Diesel powered Greyhound busses confirm that the addition of FPC-1® to the fuel will reduce fuel consumption.

The change in fuel consumption in the Greyhound bus fleet using averages on an individual bus basis is in the range of -6.2% to 15.7% with a fleet average improvement in fuel economy of 6.05%. (See tables 1 and 2)

APPENDICES

CARBON BALANCE METHOD TECHNICAL APPROACH:

A fleet of diesel powered busses operated by Greyhound Lines, Inc., was selected for the FPC-1® evaluation. The SGA-9000 exhaust analyzer and the digital thermometer instrumentation were calibrated, and a leak test on the SGA-9000 sampling hose and connections was performed. Each bus engine was then run at full throttle and brought up to stable operating temperature as indicated by the engine water, oil and exhaust temperature. No exhaust gas measurements were made until each bus engine had stabilized at the operating condition selected for the test. Number 2 diesel fuel was exclusively used throughout the evaluation.

The baseline fuel consumption test consisted of five sets of measurements of CO_2, CO, unburned hydrocarbons (measured as hexane gas), O_2, and exhaust temperature, made at 60 second intervals for the engine speed at full throttle. Other readings included ambient and fuel temperature and exhaust air velocity.

After the baseline test, the fuel storage tanks from which the fleet is exclusively fueled, was treated with FPC-1® at the recommended level of 1 ounce of catalyst to 40 gallons of diesel fuel (1:5000 volume ratio). The busses were operated with the treated fuel from January to April 1989, at which time the above test procedure was repeated for each available bus.

Throughout the entire fuel economy test, an internal self-calibration of the exhaust analyzer was performed after every two sets of measurements to correct any instrument drift. A new sampling train filter was installed before both the baseline and treated fuel test segments.

Using the carbon balance method, fuel economy is expressed as a performance factor. The performance factor is calculated from the carbon balance equation which is determined by the exhaust gas concentrations of CO_2, CO, HC, and O_2 measured during the test, the calculated molecular weight of each gas, the exhaust stream flow rate and the temperature of the exhaust stream. The above method is then used to compare baseline to treaed performance factors in determining fuel economy. The calculations are based on the assumption that the fuel characteristics, engine operating conditions and test conditions are essentially the same throughout the test.

Table 1

MOLECULAR WEIGHT OF EXHAUST GASES, ENGINE PERFORMANCE FACTORS AND FUEL ECONOMY IMPROVEMENTS FOR MAINLINER FLEET

Unit No. 9034

Mwt1	29.0119	Mwt2	29.0226
pf1	306,000	pf2	308,000
PF1	339,000	PF2	318,000

% Change F.E. = [(318,000 - 339,000)/339,000](100)

% Change F.E. = - 6.2%

Unit No. 9015

Mwt1	29.0331	Mwt2	29.0142
pf1	288,000	pf2	325,000
PF1	355,000	PF2	390,000

% Change F.E. = [(390,000 - 355,000)/355,000](100)

% Change F.E. = + 9.9%

Unit No. 9058

Mwt1	29.0441	Mwt2	29.0618
pf1	280,000	pf2	286,000
PF1	333,000	PF2	344,000

% Change F.E. = [(344,000 - 333,000)/333,000](100)

% Change F.E. = + 3.3%

Unit No. 9012

Mwt1	29.0290	Mwt2	29.0314
pf1	287,000	pf2	279,000
PF1	367,000	PF2	384,000

% Change F.E. = [(384,000 - 367,000)/367,000](100)

% Change F.E. = + 4.6%

* F.E. = Fuel Economy

Unit No. 8975*

Mwt1	29.0547	Mwt2	29.0422
pf1	270,000	pf2	282,000

% Change F.E. = [(282,000 - 270,000/270,000](100)

% Change F.E. = + 4.4%

* No exhaust velocity readings

Unit No. 8981*

Mwt1	29.0362	Mwt2	29.0118
pf1	292,000	pf2	324,000

% Change F.E. = [(324,000 - 292,000)/292,000](100)

% Change F.E. = + 11.0%

* No exhaust velocity readings

Unit No. 8940*

Mwt1	29.0018	Mwt2	28.9670
pf1	352,000	pf2	399,000

% Change F.E. = [(399,000 - 352,000)/352,000](100)

% Change F.E. = + 13.4%

* No exhaust velocity readings

Unit No. 8985*

Mwt1	29.0194	Mwt2	29.0082
pf1	314,000	pf2	314,000

% Change F.E. = [(314,000 - 314,000)/314,000](100)

% Change F.E. = 0%

* No exhaust velocity readings

Unit No. 7040

Mwt1	29.0919	Mwt2	29.0875
pf1	237,000	pf2	224,000
PF1	337,000	PF2	340,000

% Change F.E. = [(340,000 - 337,000)/337,000](100)

% Change F.E. = + .9%

Unit No. 7010

Mwt1	29.0794	Mwt2	29.1202
pf1	249,000	pf2	223,000
PF1	413,000	PF2	403,000

% Change F.E. = [(403 ,000 - 413,000)/413,000](100)

% Change F.E. = - 2.4%

Unit No. 7031

Mwt1	29.0887	Mwt2	28.9890
pf1	230,000	pf2	348,000
PF1	419,000	PF2	485,000

% Change F.E. = [(485,000 - 419,000)/419,000](100)

% Change F.E. = + 15.8%

Unit No. 7007

Mwt1	29.0434	Mwt2	28.9970
pf1	282,000	pf2	334,000
PF1	484,000	PF2	524,000

% Change F.E. = [(524,000 - 484,000)/484,000](100)

% Change F.E. = + 8.3%

Unit No. 7003

Mwt1	29.1058	Mwt2	29.0357
pf1	223,000	pf2	287,000
PF1	377,000	PF2	434,000

% Change F.E. = [(434,000 - 377,000)/377,000](100)

% Change F.E. = + 15.1%

Table 2

SUMMARY OF FUEL SAVINGS FOR MAINLINER FLEET

UNIT NUMBER	%FUEL SAVINGS
9034	- 6.2%
7010	- 2.4%
8985	0.0%
7040	+ 0.9%
9058	+ 3.3%
9012	+ 4.6%
8975	+ 4.4%
7007	+ 8.3%
9015	+ 9.9%
8981	+ 11.0%
8940	+ 13.4%
7003	+ 15.1%
7031	+ 15.8%

AVERAGE FUEL SAVINGS
78.7% / 13 = 6.05%

Figure 1
CARBON MASS BALANCE FORMULAE

ASSUMPTIONS: $C_{12}H_{26}$ and SG = 0.82
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)
CFM	=	Volumetric Flow Rate of the Exhaust
SG	=	Specific Gravity of the Fuel
VF	=	Volume Fraction
d	=	Exhaust stack diameter in inches
Pv	=	Velocity pressure in inches of H_20
Pb	=	Barometric pressure in inches of mercury
Te	=	Exhaust temperature ^{O}F

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

EQUATIONS:

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

pf1 or pf2 = $$\frac{3099.6 \text{ x } Mwt}{86(VFHC)+13.89(VFCO)+13.89(VFCO_2)}$$

CFM = $$\frac{(d/2)^2\pi}{144}\left(1096.2\sqrt{\frac{Pv}{1.325(Pb/Te+460)}}\right)$$

PF1 or PF2 = $$\frac{pf \text{ x } (Te+460)}{CFM}$$

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

Figure 2.

SAMPLE CALCULATION FOR THE CARBON MASS BALANCE

<u>BASELINE:</u>

Equation 1 (Volume Fractions)

$VFHC = 13.20/1,000,000$
$= 0.0000132$

$VFCO = 0.017/100$
$= 0.00017$

$VFCO_2 = 1.937/100$
$= 0.01937$

$VFO_2 = 17.10/100$
$= 0.171$

Equation 2 (Molecular Weight)

$$Mwt1 = (0.0000132)(86)+(0.00017)(28)+(0.01937)(44)+(0.171)(32) + [(1-0.0000132-0.00017-0.01937-0.171)(28)]$$

$$Mwt1 = 28.995$$

Equation 3 (Calculated Performance Factor)

$$pf1 = \frac{3099.6 \times 28.995}{86(0.0000132)+13.89(0.00017)+13.89(0.01937)}$$

$$pf1 = 329,809$$

Equation 4 (CFM Calculations)

$$\text{CFM} = \frac{(d/2)^2\pi}{144}\left(1096.2\sqrt{\frac{Pv}{1.325(Pb/Te+460)}}\right)$$

d =Exhaust stack diameter in inches
Pv =Velocity pressure in inches of H_20
Pb =Barometric pressure in inches of mercury
Te =Exhaust temperature ^{0}F

$$\text{CFM} = \frac{(10/2)^2\pi}{144}\left(1096.2\sqrt{\frac{.80}{1.325(30.00/313.100+460)}}\right)$$

CFM =2358.37

Equation 5 (Corrected Performance Factor)

$$\text{PF1} = \frac{329{,}809(313.1 \text{ deg F} + 460)}{2358.37 \text{ CFM}}$$

PF1 = 108,115

TREATED:

Equation 1 (Volume Fractions)

VFHC = 14.6/1,000,000
= 0.0000146

VFCO = .013/100
= 0.00013

$VFCO_2$ = 1.826/100
= 0.01826

VFO_2 = 17.17/100
= 0.1717

Equation 2 (Molecular Weight)

$$\text{Mwt2} = (0.0000146)(86)+(0.00013)(28)+(0.01826)(44)+(0.1717)(32) + [(1-0.0000146-0.00013-0.01826-0.1717)(28)]$$

$$\text{Mwt2} = 28.980$$

Equation 3 (Calculated Performance Factor)

$$\text{pf2} = \frac{3099.6 \times 28.980}{86(0.0000146)+13.89(0.00013)+13.89(0.01826)}$$

$$\text{pf2} = 349{,}927$$

Equation 4 (CFM Calculations)

$$\text{CFM} = \frac{(d/2)^2\pi}{144}\left(1096.2\sqrt{\frac{Pv}{1.325(Pb/Te+460)}}\right)$$

d =Exhaust stack diameter in inches
Pv =Velocity pressure in inches of H_20
Pb =Barometric pressure in inches of mercury
Te =Exhaust temperature ^{O}F

$$\text{CFM} = \frac{(10/2)^2\pi}{144}\left(1096.2\sqrt{\frac{.775}{1.325(29.86/309.02+460)}}\right)$$

$$\text{CFM} = 2320.51$$

Equation 5 (Corrected Performance Factor)

$$\text{PF2} = \frac{349{,}927(309.02\ \text{deg F} + 460)}{2320.51\ \text{CFM}}$$

$$= 115{,}966$$

Fuel Specific Gravity Correction Factor

Baseline Fuel Specific Gravity - Treated Fuel Specific Gravity/Baseline Fuel Specific Gravity +1

.840-.837/.840+1=1.0036

PF2 = 115,966 x Specific Gravity Correction

PF2 = 115,966 x 1.0036

PF2 = 116,384

Equation 6 (Percent Change in Engine Performance Factor:)

$$\% \text{ Change PF} = \frac{\text{PF2 - PF1}}{\text{PF1}} \times 100$$

$$\% \text{ Change PF} = [(116{,}384 - 108{,}115)/108{,}115](100)$$

$$= +7.65$$

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