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 by Wepfer Marine, Presidents Island, TN, 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 16V92 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 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 Bacharach True-Spot smokespot meter to determine the density of exhaust smoke.

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.

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.

The Gail S, a twin screw harbor tug powered by 16V92 main engines was tested for both baseline and treated fuel segments. On both occasions, the engines were loaded by pushing at full throttle against a loaded barge. Table 1 below summarizes the percent change in fuel consumption.

Table 1: Summary of Carbon Balance Fuel Consumption Changes

Main	Engine	RPM	% Change Fuel Consumption
Port	16V92 Detroit	1850	- 6.18
Starboard	16V92 Detroit	1850	- 5.87

DISCUSSION

1. Change in Exhaust Smoke Density

Both main engines smoked excessively using baseline (untreated) diesel fuel. The smoke density numbers recorded during full throttle operation were completely off the scale (9+). After approximately four weeks (400 hours) of FPC-1 fuel treatment, smoke density was reduced from a 9+ reading at baseline to a 7.5 with FPC-1® treated fuel on the starboard main. Smoke was not measurably reduced on the port main engine. This is likely due to camshaft lobe wear on the port engine (see discussion below).

Table 2 in the Appendices summarizes the changes in smoke density.

2. Emissions Changes

Baseline CO and HC emissions averaged .070% and 8.0 part per million (ppm) for the starboard engine and .050% and 6 ppm for the port engine. After FPC-1 treatment and proper engine preconditioning, CO and HC were reduced to .055% and 5.7 ppm on the starboard main. CO increased on the port main (.090%) while HC remained virtually unchanged. These data correspond with the data from the smoke density test. Again, it is felt that the FPC-1 catalyst was hindered by the lobe wear on the camshaft for the port main. Table 3 summarizes the emissions data.

3. Increase in RPM During Treated Fuel Test Segment

During baseline fuel consumption and emissions testing, the Gail S. was loaded by pushing at full rack or throttle against a loaded barge for approximately 25 minutes. Engine rpm were recorded using a photo tachometer and magnetic tape attached to the flywheel. Maximum rpm seen was 1840 for the starboard main and 1850 for the port.

During the treated fuel test segment, the Gail S. was again loaded by pushing against a loaded barge at full rack, however, this time rpm increased to 1870 on the starboard main and 1880 on the port main. UHI technicians attempted to reduce engine speed back to baseline by having the pilot back off on the throttle, however the throttle control was not sensitive enough to reproduce the exact baseline rpm. Therefore, the treated fuel test was finally conducted at engine speeds of 1870 to 1875 for both engines.

4. Port Main Engine Wear

After completing the treated fuel segment of the Wepfer Marine test, a discussion was held between UHI technicians and Mr. Rick Prince of Wepfer Marine. The discussion centered around the increase in engine rpm at full throttle, and the lack of response in terms of reduced emissions (smoke and CO) on the port main.

During our discussion, Mr. Prince explained that the port engine had considerable camshaft lobe wear. The lobe wear would reduce the travel and the length of time the exhaust valve is open, preventing the valve from opening as far or staying open as long as it is designed to during the scavenge or exhaust stroke. Consequently, more of the exhaust gases would remain in the combustion chamber after the power stroke. This would have the effect of enriching the fuel/air ratio. Apparently, the fuel/air ratio has been altered enough to interfere with the FPC-1 catalyst's ability to effect a cleaner combustion of the fuel on the port main. However, the product still effected a fuel consumption reduction, a result observed in other tests, including the study at Southwest Research Institute.

Mr. Prince noted there is little to no wear on the starboard main's camshaft, therefore the engine is functioning near it's designed efficiency and fuel/air ratio. The starboard engine experienced typical reductions in smoke density and gaseous emissions (CO & HC), along with a significant reduction in fuel consumption.

CONCLUSIONS

1) The fuel consumption change determined by the carbon balance method ranged from a - 5.87% to - 6.18%. The two main engines averaged a 6.025% reduction in fuel consumption.

2) Smoke density using the Bacharach smokespot was reduced 16.66% in the starboard main; FPC-1 had no effect on smoke density on the port main, probably due to the camshaft lobe wear mentioned in the discussion.

3) Unburned hydrocarbons and carbon monoxide emissions were reduced 29.1% and 21.4%, respectively, on the starboard main after FPC-1 fuel treatment. HC emissions remained unchanged after FPC-1® treatment on the port main, however, CO increased from .05% to .09%. Again, the lack of improvement in emissions on the port engine are likely a result of inefficiencies created by the camshaft wear.

APPENDICES

Appendix 1

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 tugboat's main engines were brought up to operating temperature at a set rpm while pushing against a loaded barge, 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 2: Smoke Density Comparison

Main	Base Smoke #	FPC-1® Treated Smoke #	% Change
Starboard	9.00	7.50	-16.67
Port	9.00	9.00	0.00
Fleet Average:	9.00	8.25	- 8.34

Table 3: Summary of Emissions Data

	Base Fuel				FPC-1® Fuel			
Main	CO%	HC	CO2%	RPM	CO%	HC	CO2%	RPM
Starboard	.070	8.00	4.692	1840	.055	5.67	4.637	1875
Port	.050	6.00	5.017	1850	.090	6.67	4.533	1875
FLEET AVE.	**.060**	**7.00**	**4.854**	**1845**	**.064**	**6.17**	**4.585**	**1875**

Table 4 Summary of Barometric Pressure Readings

Base	30.15 "Hg
Treated	30.40 "Hg

Carbon Balance Calculation of Fuel Consumption Changes

Table 5
Starboard Main/1850 RPM

Mwt1	29.3392	Mwt2	29.3042
pf1	130,817	pf2	132,649
PF1	41,865	PF2	44,322

% Change PF = [(44,322 - 41,865)/41,865](100)

***% Change PF = + 5.87%**

Table 6
Port Main/1850 RPM

Mwt1	29.3755	Mwt2	29.2777
pf1	123,133	pf2	134,488
PF1	39,782	PF2	42,239

% Change PF = [(42,239 - 39,782)/39,782](100)

***% Change PF = + 6.18%**

* 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 (^{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:

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

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

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

FUEL ECONOMY:
PERCENT INCREASE (OR DECREASE)

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

Appendix 7

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)

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.