EVALUATION OF FPC-1® FUEL PERFORMANCE CATALYST

AT

MARITRANS OPERATING PARTNERS

REPORT PREPARED BY

UHI CORPORATION

PROVO, UTAH

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Introduction

A test program to determine the effect of the FPC-1® combustion catalyst on fuel consumption in marine propulsion engines was conducted by Maritrans Operating Partners, Inc., Philadelphia, Pa. The test was conducted under the direction of Mr. Bob Corney, East Coast Fleet Marine Engineer for Maritrans.

Changes in fuel consumption were determined with an indirect carbon balance technique (based on the measurement of the carbon containing exhaust gases under steady-state engine conditions) and a direct measurement of gallons consumed per hour (gph) from engine room fuel flow meters and on-board computers.

Background

·Recognized Laboratory Testing

At the time of the Maritrans test program, FPC-1® had already undergone extensive engine testing in independent EPA recognized and university laboratories. Test procedures were also recognized and included the EPA - Federal Test Procedures (FTP) and Highway Fuel Economy test (HFET), a steady-state engine dynamometer test at Brigham Young University, and Society of Automotive Engineer (SAE) road tests (SAE-J1082). Laboratory tests and road tests, in both gasoline and diesel powered vehicles, demonstrated FPC-1® creates fuel savings of 2% to 10% in light duty passenger vehicles.

·Customer Testing in the Field

Further, over a decade of field testing, primarily in high-speed, heavy duty diesel engines, substantiated the laboratory and road test results. These tests suggest an average in-use improvement in fuel economy greater than that predicted by the EPA and SAE tests.

Long term field studies have also shown the catalyst inhibits the formation of hard carbon deposits on pistons, valves and in the ring zone area, while gradually removing pre-existing carbon deposits. Oil analysis further documents reduced soot contamination and engine wear after long term FPC-1® catalyst use, all of which indicates reduced maintenance and operating costs.

Because of the substantial data indicating the potential for reduced operating costs, after several meetings with Mr. Bob Corney, Marine Engineer for Maritrans, it was decided to conduct several studies to determine the effect of FPC-1® on large medium speed engines powering the Maritrans fleet.

Test Procedures

The two fuel consumption tests utilized by Maritrans and UHI involved the measurement of exhaust gases with a non-dispersive infrared (NDIR) analyzer, and volumetric flow rate measurement using in line flow meters and on-board computers while the main engines operated under steady-state conditions.

The carbon balance method produces a value of fuel consumption with FPC-1® relative to a baseline value established with the same engine. Engine speed and load were duplicated from test to test, and measurements of exhaust and ambient temperature are made to perform appropriate corrections.

Exhaust concentrations of $C0_2$, CO, HC, and 0_2 are measured by a Sun Electric Corporation (SGA-9000). The SGA-9000 is approved by the EPA for engine emissions analysis and is calibrated internally using calibration gases recommended by Sun Electric. Specifications for the analyzer are given in Appendices.

Technical Approach

The test fleet selected by Mr. Corney for the FPC-1® test included the tugboats Pathfinder, Voyager II, and Mariner. The tugboats are powered by main engines representative of the entire Maritrans fleet (Cat 399, EMD 567BC and 645E engines).

The tugboats were loaded by pushing at a fixed engine speed (rpm) against the dock. Engine rpm and load where maintained throughout the approximately 45 minute per tugboat test allowing for the accumulation of many data points.

The SGA-9000 exhaust analyzer and the thermocouple instrumentation were calibrated and a leak test on the sampling hose and connections was performed while the main engine(s) for each tugboat were then brought up to stable operating temperature as indicated by engine water and oil temperature, engine manifold, and exhaust temperature.

Baseline data for the carbon balance method consisted of multiple measurements of CO_2, CO, unburned hydrocarbons (measured as CH_4), O_2, and exhaust temperature, made at 60 second intervals for each engine tested. Fuel flow rate was measured from the on-board computer at similar intervals. Engine speed and cylinder temperatures were recorded at regular intervals from both the engine room and the on-board computer.

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

After baseline data accumulation, the fuel tanks on-board the three tugboats were treated with FPC-1® at a 1:5000 mixing ratio. The tugs then operated as normal, treating fuel as it was taken on (except the Voyager II), for approximately one month. Then the tests were repeated at identical engine rpm and load, under nearly identical ambient conditions. All instrument calibrations, readings and procedures were reproduced and verified by Mr. Corney who observed every aspect of the test.

Discussion

The indirect or carbon mass balance method uses the exhaust gas concentrations measured during the tests to calculate "engine performance factors" which relate the fuel consumption of the treated fuel to the baseline fuel (untreated). The calculations are based on the assumption that the fuel characteristics, engine operating conditions and test conditions are essentially the same throughout the test. The carbon balance equations are found in the appendices.

Tables 4, 5 and 6 show the calculated volume fractions, average molecular weight of the gases, and the engine performance factors for the treated and baseline test on the starboard main engine for the Pathfinder and Voyager II, and for the single Mariner main engine.

The Pathfinder is powered by Cat 399 engines. The Voyager 11 is powered by twin EMD 567-BC main engines. The Mariner is powered by a single EMD 645E main engine. The raw data are summarized in Table 1 for the Pathfinder, Table 2 for the Voyager II, and Table 3 for the Mariner.

The Voyager II was first tested with FPC-1® treated fuel as the baseline. The catalyst was then removed from the system by diluting the treated fuel in the tanks with large volumes of untreated fuel. The other boats were first tested with untreated fuel, and later with FPC1® treated fuel.

Results

The changes in fuel consumption for each main engine are shown below by test method.

Tugboat	Test Method	% Change Fuel Consumption
Pathfinder	carbon balance	-1.53%
Pathfinder	direct gph	-3.64%
Voyager II	carbon balance	-3.95%
Voyager II	direct gph	-5.36%
Mariner	carbon balance	-8.20%
Mariner	direct gph	-5.00%

Crew Observations

Mr. Corney and several of the chief engineers noted marked reduction in engine smoking after a few weeks of FPC- 1® treatment. Air boxes on the EMD's were cleaner. Cylinder temperatures, documented from engine room log entries and during the treated fuel segment of the test, were also reduced (see attached bulletin in appendices).

Conclusions

The following conclusions may be made from the results of the FPC-1® evaluation conducted for Maritrans Operating Partners, Inc.:

> The addition of FPC-1® to the diesel fuel used by the Maritrans test fleet resulted in fuel economy improvements ranging from 1.53% to 8.20%, using the carbon balance test method to determine fuel consumption.
>
> The addition of FPC-1® to the diesel fuel used by the Maritrans test fleet resulted in fuel economy improvements ranging from 3.64% to 5.36%, using the direct measurement in gallons per hour from the on-board computers and flow meters.
>
> The addition of FPC-1® appeared to have a positive effect upon exhaust smoking and cylinder temperature.

Table 1

Summary of Exhaust and GPH Measurements
During Baseline and Treated Fuel Tests
From the Pathfinder

1100 RPM

	CO	HC	C02	02	Exh. Temp.	GPH
Control	0.0144%	22.2ppm	9.68%	7.90%	858.40 °F	55
Treated	0.0117%	21.5ppm	9.54%	8.73%	882.50 °F	53

Table 2

Summary of Exhaust and GPH Measurements
During Baseline and Treated Fuel Tests
From the Voyager 11

600 RPM

	CO	**HC**	**C02**	**02**	**Exh. Temp.**	**GPH**
Control	0.01%	16.4ppm	4.61%	15.41%	573.6 °F	56
Treated	0.01%	23.28ppm	4.42%	14.54%	572.0 ° F	53

Table 3

Summary of Exhaust and GPH Measurements During Baseline and Treated Fuel Tests From the Mariner

750 RPM

	CO	**HC**	**C02**	**02**	**Exh. Temp.**	**GPH**
Control	0.068%	22.2ppm	6.92%	11.84%	898.0 ° F	60
Treated	0.039%	21.7ppm	6.42%	13.70%	867.9 ° F	57

Table 4

Volume Fractions for the Pathfinder Data

	Control	**Treated**
VfCO	0.000144	0.000117
VfHC	0.0000222	0.0000215
$VfC0_2$	0.0968	0.0954
$Vf0_2$	0.0790	0.0873

Total Molecular Weight and Performance Factors

Mwtl	29.8661	**Mwt2**	29.8768

pf_l	65391.0347	**pf_2**	66390.7381

% Change in P.F. = 66390.7381 - 65391.0347 = 999.7034

$$\frac{999.7034}{65391.0347} \times 100 = \mathbf{+1.53\%}$$

Table 5

Volume Fractions for the Voyager 11 Data

	Control	**Treated**
VfCO	0.0001	0.0001
VfHC	0.0000164	0.00002328
$VfC0_2$	0.0461	0.0442
$Vf0_2$	0.1541	0.1454

Total Molecular Weight and Performance Factors

Mwtl	29.3550	**Mwt2**	29.2902
pf_l	134753.886	**pf_2**	140076.522

% Change P.F. = 140076.522-134753.886 = 5,322.6360

$$\frac{5,322.6360}{134753.886} \times 100 = \mathbf{+3.95\%}$$

Table 6

Volume Fractions for the Mariner Data

	Control	Treated
VfCO	0.00068	0.00039
VfHC	0.0000222	0.0000217
$VfC0_2$	0.0692	0.0642
$Vf0_2$	0.1184	0.137

Total Molecular Weight and Performance Factors

Mwtl	29.5821	**Mwt2**	29.5765
pf_1	89800.9148	**pf_2**	97156.2840

% Change P.F. = 97156.2840-89800.9148 = 7,355.3692

$$\frac{7{,}355.3692}{89800.9148} \times 100 = \mathbf{+8.20\%}$$

Appendices

Memorandum Report

TO: Mr. Carl Dittrich and Mr. Bob Corney

FROM: S. Craig Flinders, UHI Corporation

DATE: June 15, 1988

RE: FPC-1® Phase II Field Test Results

Gentlemen:

Enclosed are the results of the Phase II carbon balance/volumetric flow rate fuel consumption test recently conducted with three Maritrans tugboats. Table 1 below summarizes the fuel economy improvements created by the addition of FPC-1® to the fuel.

Table 1

Phase II Carbon Balance Fuel Consumption Comparison

Tugboat	Base Fuel PF	FPC-1® PF	%Improvement
Ranger	67,097.00	70,596.00	5.2
Voyager 11	116,955.00	121,659.00	4.0
Schuylkill	69,359.00	70,900.00	2.2

The Voyager II was the only tugboat equipped with an temperature compensating, in-line flow meter and on-board computer. The volumetric fuel consumption (vfc) in gallons per hour (gph) was taken at regular intervals throughout the entire test (approx. 45 minutes total running time). Table 2 gives the average rate of fuel usage with and without FPC-1® fuel treatment while pushing against the dock at an engine speed of 650 rpm.

Table 2

Phase II Volumetric Fuel Consumption Comparison (Voyager II only, Starboard Main)

Base Fuel Ave. GPH	FPC-1@ Ave. GPH	% Improvement
73	69	5.5

The results of the Phase II test are consistent with those already demonstrated during Phase I testing with the Voyager II, Pathfinder, and Mariner tabled below (Tables 3 and 4).

Table 3

Phase I Carbon Balance Fuel Consumption Comparison

Tugboat	Base Fuel PF	FPC-1® PF	%Improvement
Pathfinder	65,391.00	66,391.00	1.5

Voyager II	134,754.00	140,077.00	4.0
Mariner	89,801.00	97,156.00	8.2

Table 4

Phase I Volumetric Fuel Consumption Comparison

Tugboat	Base Fuel Ave. GPH	FPC-1® Ave. GPH	% Improvement
Pathfinder	55	53	3.6
Voyager II	56	53	5.4
Mariner	60	57	5.0

The tests on six tugboats representing all major engine types used in the fleet (Cat 398, 399, Cummins KTA 2300, EMD 567 and 645) using both the carbon balance (cb) and vfc measurement from on-board computers indicate an average fuel consumption reduction with FPC-1® fuel treatment of 4.5%. The average reduction is nearly 5% if the volumetric fuel consumption test is considered alone.

Crew observations include reduced engine smoking (the Voyager, Mariner and Ranger), lower cylinder temperature (20 to 50 degrees F, the Mariner and Schuylkill) and cleaned air boxes (the Voyager).

Engine life and comparative engine carbon residue buildup studies done by Mr. Corney have also been positive. As you know, the Cat 399 main engines powering the Defender were rebuilt some time ago. These engines had never exceeded 12,000 hours of operation before exhaust valves began to fail. After re-power and FPC-1® fuel treatment, the 399 mains achieved over 17,000 hours of operation before exhaust valve failure occurred. This increase in valve life is likely due to FPC-1®'s ability to remove existing carbon deposits and prevent future buildup, as well as to the demonstrated reductions in cylinder temperatures.

I trust this information is satisfactory. I look forward to our next meeting to discuss the results of the Maritrans FPC-1® Test Program, and the possible system wide use of FPC-1®. In the meantime, if you have any questions, please feel free to call.

SUMMARY OF FPC-1® TESTING BY MARITRANS OPERATING PARTNERS

Under the direction of Mr. Bob Corney, East Coast Fleet Marine Engineer for Maritrans Operating Partners, tugboats powered by typical marine propulsion diesel engines were tested with and without FPC-1® fuel catalyst. Fuels savings averaging 4.5% were documented during both carbon balance (indirect method) and specific fuel consumption tests (using in-line flow meters and on-board computers) while main engines were operated under steady-state engine conditions. In addition to the measured reduction in fuel consumption, several engines smoked less and experienced cylinder temperature reductions of 20 to 50 degrees F while running on FPC-1® treated fuel.

Table 1. 1987 Test

Percentage Fuel Savings

Vessel	Carbon Balance	Boat Fuel Monitor	Crew Observations
Voyager II (EMD 567)	3.95	5.36	Less smoke
Pathfinder (Cat 399)	1.53	3.64	Cleaned fuel tanks
Mariner (EMD 645)	8.20	5.00	Less smoke Lower cylinder temp.

Table 2. 1988 Test

Percentage Fuel Savings

Vessel	Carbon Balance	Boat Fuel Monitor	Crew Observations
Voyager II (EMD 567)	4.02	5.48	Cleaned air boxes

Ranger (Cat 398)	5.20		
Schuylkill (Cummins 2300)	2.22		Less Smoke Lower cylinder temp.
Average Fuel Savings:	**4.18%**	**4.87%**	

The composite fuel savings for all ten tests is 4.5%. Maritrans consumes approximately 10,000,000 gallons of marine diesel per year. Assuming a fuel cost of $7,000,000 a year, the use of FPC-1® will reduce Maritrans fuel cost approx. $292,000.

With lowered cylinder temperatures, engine life can be extended. Reduced engine smoking equates to reduced engine hard carbon accumulation and cleaner motor oil. Reduced engine smoking also helps alleviate environment pressures.

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

$VFC0_2$ = "reading" / 100

$VF0_2$ = "reading" / 100

VFHC = "reading" / 1,000,000

VFCO = "reading" / 100

Equations:

$$Mwt = (VFHC)(86)+(VFCO)(28)+(VFC0_2)(44)+(VF0_2)(32)+[(1-VFHC-VFCO-VF0_2-VFC0_2)(28)]$$

$$pf_1 \text{ or } pf_2 = \frac{2952.3 \times Mwt}{89(VFHC)+ 13.89(VFCO)+ 13.89(VFC0_2)}$$

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

Fuel Economy:

$$\text{Percent Increase (or Decrease)} = \frac{(PF_2 - PF_1) \times 100}{PF_1}$$

Bid Specifications

- %02:0-25%
- PPM HC: 0-2000 ppm
- %CO: 0-10%
- %C02:0-20%
- Warm-up: 15 minutes @ 70°-110°F: 20 minutes @ 35°F
- System Accuracy: HC, CO, 02 & C02:±3% of full scale
- Temperature Range: 35°-110°F operating; -20° to 130°F storage.
- Relative Humidity: Up to 85% non-condensing

- Interference Effects: Less than ± 10 ppm HC or ± .05% CO of full scale (low range)
- System Response Time: 7 seconds for 90% response of full scale
- Drift: +3% of full scale in one hour
- Repeatability: Less than +2% of full scale
- Power: 115V ac, 60Hz @ 4.5A
- Circuit Protection: Circuit breaker protection provided for the main console and infrared
- Dimensions: 15" Lx7-3/4" H x 19" D (38 x 19 x 38cm)
- Shipping Weight: 65 lbs. (45kg) without stand
- Construction: All metal housing painted with blue textured enamel, resistant to oil, gasoline, chipping and scratching

Accessories

- Stainless steel exhaust pickup probe and 25 feet (8m) of sample hose
- Literature including Operator's Manual and quick Reference Guide
- RS-232 printer port
- Extra Filters
- Leak check adapter
- Anti-Dilution probe adapters (optional)
- Calibration gas bottle and mounting (optional)