Customer Trial Evaluation

of

Fuel Performance Catalyst - 1 (FPC-1)

by

Maritrans Operating Partners

Philadelphia, PA

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Report prepared for Maritrans Operating Partners

by

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Abstract

A test program to determine the effect of FPC-1 fuel catalyst on fuel consumption in a tugboat fleet was conducted by Maritrans Operating Partners, Inc., Philadelphia, Pa. The fleet test was conducted under the direction of Mr. Bob Corney, East Coast Fleet Marine Engineer for Maritrans. The test ran from September to November 1987.

Changes in fuel consumption were determined by an indirect method or carbon balance technique based on the measurement of the carbon containing exhaust gases under steady-state engine conditions, and a direct fuel measurement of gallons consumed per hour (gph) off of engine room fuel flow meters. Results of the test verify the FPC-1 catalyst can provide fuel cost savings for diesel power tugboat fleet operators.

Introduction

This report summarizes the results of field tests conducted on a select fleet of Maritrans Operating Partners' tugboats. The objective of the test was to determine if the addition of FPC-1 to the diesel fuel would reduce fuel consumption.

FPC-1 had undergone extensive engine testing in independent EPA recognized laboratories, in a university laboratory, and in many long term field tests. Test procedures included the EPA standardized Federal Test Procedures (FTP) and Highway Fuel Economy test (HFET). These tests, in both gasoline and diesel powered vehicles, have demonstrated the additive can provide fuel savings of 2% to 10%, depending upon factors such as the operation and condition of the equipment, and the fuel quality.

Other tests include the Society of Automotive Engineers (SAE) J-1082 Suburban and Interstate Test Cycles, the Coordinated Research Council cold start driveability test, and a computerized steady state engine dynamometer test.

Over a decade of field testing, primarily in heavy duty diesel fleets, substantiates the laboratory and road test results, and suggests an average in-use improvement in fuel economy greater than that predicted by the EPA and SAE test. Field applications have also shown that the additive inhibits the formation of hard carbon deposits on pistons, valves and other combustion chamber surfaces, and gradually consumes pre-existing carbon deposits, which potentially further reduces maintenance and operating costs.

Measurement of Fuel Economy - Carbon Balance and Direct Measurement

Until late 1973, vehicle fuel consumption was measured primarily by various test track or road test procedures. In September 1973, the U.S. Environmental Protection Agency utilized a carbon balance method to determine fuel economy in conjunction with its chassis dynamometer vehicle emissions test. This method relies on measurements of vehicle exhaust flow and emissions rather than direct measurement of fuel consumption.

By 1974, the carbon balance method was used solely in the EPA cold start emissions test cycle (LA-4 Cycle). In 1975, the cycle was modified by adding a hot start, and was known as the

Federal Test Procedure (FTP). Later a highway driving simulation was developed which is known as the Highway Fuel Economy Test (HFET).

A series of tests by Ford compared techniques of direct measurement of fuel consumption (volumetric or gravimetric) to the carbon balance method. The results, published as SAE Paper 75002, entitled "Improving the Measurement of Chassis Dynamometer Fuel Economy," stated

> "...fuel economy results obtained by carbon mass balance calculation of carbon containing components in the vehicle exhaust are at least as accurate and repeatable as those obtained by direct fuel measurement of fuel consumed."

The study also determined that the critical factors in the measurement of fuel consumption with the carbon balance method are the measurement of CO_2, the use of standardized test equipment and procedures, and correction for differences in ambient conditions. The complete paper is included in Appendix A.

UHI Test Procedures

The fuel consumption test method utilized by Maritrans and UHI involves exhaust gas measurements of a stationary vehicle, in this case, tugboats. The method produces a value of equipment fuel consumption with FPC-1 relative to a baseline value established with the same equipment. Although the test is not as controlled as a laboratory test, care is taken to ensure consistency and accuracy. Engine speed and load are duplicated from test to test, and measurements of exhaust and ambient temperature are made to perform appropriate corrections. The carbon balance method represents a practical, economic and repeatable approach to determine relative fuel consumption in the field.

Exhaust gases are analyzed by state-of-the-art infrared (NDIR) exhaust gas analyzers made by the Sun Electric Corporation (SGA-9000) to measure CO_2, CO and unburned hydrocarbons, which are all carbon-containing exhaust gases. In addition, oxygen concentration in the exhaust is measured. 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 Appendix B.

Technical Approach

A fleet of diesel powered tugboats owned and operated by Maritrans Operating Partners, Inc., was selected, in consultation with Mr. Bob Corney, for the FPC-1 evaluation. The fleet included the tugboats Defender, Pathfinder, Voyager II, and Mariner.

The SGA-9000 exhaust analyzer and the thermocouple instrumentation were calibrated and a leak test on the sampling hose and connections was performed. The main engine(s) for each tugboat was then brought up to stable operating temperature as indicated by the engine manifold temperature and exhaust temperature. Marine diesel fuel was exclusively used throughout the evaluation.

The baseline fuel consumption test consisted of several sets of 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.

The Defender and Pathfinder are powered by Cat 399 engines. Both of the Defender Cat 399 main engines were tested in a much earlier test program. Only the starboard main Cat 399 engine was tested onboard the Pathfinder.

The Voyager II is powered by twin 567-BC EMD main engines. The Voyager II starboard main engine was tested. The Mariner's single 645-E EMD main engine was tested. Both the 567 and 645 EMD engines are similar to the engines used to power locomotives and are manufactured by the same company.

The measurements are summarized in Table 1 for the Pathfinder and in Table 2 for the Voyager II. Table 3 summarizes the Mariner measurements. The results of the Defender test are found in a separate report contained in it's entirety in Appendix C. The actual measurements for the Pathfinder, Voyager II, and Mariner are contained in Appendix D.

After the baseline test, the fuel tanks onboard the Defender, Pathfinder and Mariner were treated with FPC-1 at the recommended level of 1 oz. of additive to 12.5 gallons of diesel fuel (1:1600 volume ratio). The tugboats were then operated with the treated fuel for approximately one month and the fuel consumption test described above was repeated for each tugboat.

The Voyager II test was performed first with FPC-1 treated fuel as the baseline. The additive was then gradually removed from the system by diluting the FPC-1 treated fuel in the Voyager tanks with large volumes of untreated fuel over approximately one month of testing.

The measurements for the tugboats with treated fuel are summarized in Tables 1, 2, and 3, and the actual measurements are also contained in Appendix D. The gallons per hour measurements for the Pathfinder, Voyager II, and Mariner are also found on Tables 1, 2 and 3.

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.

From the exhaust gas concentrations measured during the test, 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 the fuel characteristics, engine operating conditions and test conditions are essentially the same throughout the test. The equations are found in Appendix E. Tables 4 and 5 give the average volume fraction and molecular weight of each constituent for treated and baseline test for the starboard main engine on the tugboats Pathfinder and Voyager II, and Table 6 gives the same information for the single Mariner engine.

Results

Table 4 shows the performance factors for the Pathfinder for the baseline and treated fuel tests. Table 5 shows the performance factors for the treated and return to baseline fuel tests onboard the Voyager II. Table 6 shows the performance factors for the Mariner.

The improvements in fuel economy for each tugboat are summarized below by test method and tugboat.

Tugboat	Test Method	Percent Improvement
Pathfinder	carbon balance	1.53%
Pathfinder	direct gph	3.64%
Defender	carbon balance	9.40%
Voyager II	carbon balance	3.95%
Voyager II	direct gph	5.66%
Mariner	carbon balance	8.20%
Mariner	direct gph	5.00%

A qualitative comparison smoke particulate reduction was also performed during the Pathfinder, Voyager II, and Mariner baseline and treated fuel tests. A 25 micron filter trapped smoke particles before the exhaust gases were passed through the exhaust gas analyzer. The additive treated filter was subjected to diesel exhaust for 30 minutes while testing the Pathfinder and Voyager II. The baseline filter was subjected to diesel exhaust 11 minutes while testing the Pathfinder. The length of time that the filter trap was subjected to diesel emissions while testing the Voyager II was not recorded by the technicians, however, the Voyager II baseline test was run for no less than 15 minutes.

Both treated and baseline filter traps were subjected to diesel exhaust 15 minutes during the Mariner test.

A visual comparison of the filters showed the engines smoked less while running on FPC-1 treated fuel.

Discussion

Laboratory and field studies indicate that the effect of FPC-1 on fuel economy is twofold. First, it appears to reduce the length of time required to burn the fuel in the combustion chamber, thereby, producing more usable energy per unit volume of fuel.

Second, FPC-1 involves existing hard carbon deposits in the combustion process causing these to be removed from the engine. These two effects combine to create an overall improvement in engine performance and, therefore, fuel economy. Consequently, tests on new engines and engines with low hours of operation show smaller improvements in fuel economy than older, high hour engines that have a buildup of carbon deposits.

Both the Pathfinder and the Voyager II had been treated with FPC-1 for extended periods of time prior to this final test for fuel economy. FPC-1 was taken out of the Pathfinder fuel system approximately two months before the beginning of this test program. The additive was added to the fuel again after baseline testing.

The Voyager II was consuming fuel with a diluted treatment ratio of FPC-1 at the time of treated fuel testing. FPC-1 was no longer added to the fuel after treated fuel testing and while attempting to return to untreated engine condition. Still, it is likely that the Voyager II ran on FPC-1 treated fuel, although diluted, through much of return to baseline period.

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 9.4%, using the carbon balance test method and the measured reduction in carbon containing exhaust gases to measure fuel consumption.

* The addition of FPC-1 to the diesel fuel used by the Maritrans test fleet resulted in fuel economy improvements ranging from 3.6% to 5.7%, using the direct measurement in gallons per hour from the onboard fuel flow meters.

* The addition of FPC-1 to the five engines tested on the four tugboats resulted in a fleet average improvement in fuel economy of 5.34%.

* The qualitative exhaust analyzer filter trap inspection showed a marked reduction in particulates or soot in the exhaust gasses with the fuel treated with FPC-1.

* Carbon monoxide (CO) levels were reduced 20.5% with additive treatment, while unburned hydrocarbon (HC) levels increased 7.46%.

Table 1

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

1080 RPM

	CO	HC	CO2	O2	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 Measurements
During Baseline and Treated Fuel Tests
From the Voyager II

614 RPM

	CO	HC	CO2	O2	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 Measurements
During Baseline and Treated Fuel Tests
From the Mariner

760 RPM

	CO	HC	CO2	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
VfCO2	0.0968	0.0954
VfO2	0.0790	0.0873

Total Molecular Weight and Performance Factors

Mwt1	29.8661	Mwt2	29.8768
pf1	65391.0347	pf2	66390.7381

Percent Change in Fuel Flow

$$66390.7381 - 65391.0347 = 999.7034$$

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

Table 5

Volume Fractions for the Voyager II Data

	Control	**Treated**
VfCO	0.0001	0.0001
VfHC	0.0000164	0.00002328
VfCO2	0.0461	0.0442
VfO2	0.1541	0.1454

Total Molecular Weight and Performance Factors

Mwt1	29.3550	**Mwt2**	29.2902
pf1	134753.886	**pf2**	140076.522

Percent Change in Fuel Consumption

140076.522-134753.886 = 5,322.6360

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

Table 6

Volume Fractions for the Mariner Data

	Control	Treated
VfCO	0.00068	0.00039
VfHC	0.0000222	0.0000217
VfCO2	0.0692	0.0642
VfO2	0.1184	0.137

Total Molecular Weight and Performance Factors

Mwt1	29.5821	**Mwt2**	29.5765
pf1	89800.9148	**pf2**	97156.2840

Percent Change in Fuel Consumption

$$97156.2840 - 89800.9148 = 7{,}355.3692$$

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