AN EVALUATION OF FPC-1 FUEL PERFORMANCE CATALYST

BY

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UHI TECHNICAL REPORT

Abstract

A test program to determine the effect of FPC-1 fuel catalyst on the fuel economy of the R.E. Pierce fleet of trucks, in Harrisville, Pennsylvania, was conducted under the direction of Ed Nusser with RDP Inc., and Bunk Pierce, owner of Pierce Trucking. The reduction in fuel consumption was determined from a carbon-balance method which is based on measurements of the exhaust gases from the trucks. Results of the test show that the catalyst can provide cost savings up to 7.4% for the diesel fleet which was evaluated.

Introduction

This report summarizes the results of field tests conducted on R.E. Pierce fleet trucks to measure the reduction in fuel consumption due to an iron-based fuel catalyst, FPC-1.

The fuel catalyst, an aftermarket product containing ferrous picrate, has been subjected to extensive engine testing in independent laboratories at universities and Environmental Protection Agency (EPA) recognized facilities. These tests, in both gasoline and diesel powered vehicles, have demonstrated that the catalyst can provide fuel savings ranging from about 2% to 10%, depending upon factors such as the operation and condition of the equipment, and the fuel quality.

The tests have included the EPA Federal Test Procedure (FTP) and Highway Fuel Economy Test (HFET), the Society of Automotive Engineers (SAE) J-1082 Suburban and Interstate Test Cycles, CRC cold start driveability test, and a computerized engine dynamometer test sequence.

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 catalyst 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.

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 Motor Company 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 UHI and RDP involves exhaust gas measurements of a stationary vehicle. No chassis dynamometer is required so driver error and tire/roll slippage are eliminated as sources of inaccuracy. The method produces a value of equipment fuel consumption with FPC-1 relative to a baseline value established with the same vehicle. 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 and pressure 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 vehicle 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 trucks owned and operated by R.E. Pierce was selected for the FPC-1 evaluation. Table 1 shows the engine and mileage of the six vehicles used throughout the test. All trucks which were originally included in the baseline test fleet were also included in the treated segment of the evaluation.

The SGA-9000 exhaust analyzer and the thermocouple instrumentation were calibrated and a leak test on the sampling hose and connections was performed. Each truck engine was then brought up to stable operating temperature as indicated by the engine water temperature and exhaust temperature. No exhaust gas measurements were made until each truck engine had stabilized at the operating condition selected for the test. No. 2 diesel fuel was exclusively used throughout the evaluation.

The baseline fuel consumption test consisted of five sets of measurements of CO2, CO, unburned hydrocarbons (measured as CH4), O2, and exhaust temperature, made at 30 second intervals for each engine test speed of 1900 rpm and 1600 rpm. The measurements are summarized in Table 2, and the actual measurements are contained in Appendix C.

After the baseline test, on October 3, 1987, the fuel storage tank, from which the fleet is exclusively fueled, was treated with FPC-1 at the recommended level of 1 oz. of catalyst to 12.5 gallons of diesel fuel (1:1600 volume ratio). The trucks were then operated with the treated fuel and accumulated an average of 5613 miles per truck when, on November 2, 1987, the fuel consumption test described above was repeated for each truck. The measurements for the trucks with treated fuel are also summarized in Table 2, and the actual measurements are contained in Appendix D.

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.

Engine operating speeds of 1600 rpm and 1900 rpm were selected to demonstrate the correlation of the exhaust analysis with fuel consumption. Though the higher engine speed is more realistic, less fuel would be consumed by the engine operating at the lower speed for the same load. For a diesel engine with no air flow throttling, this will result in lower volumetric concentrations of carbon-containing exhaust gases, which can be observed from the measurements obtained from the exhaust analyzer during the evaluation.

From the exhaust gas concentrations measured during the test, the molecular weight of each constituent, and the temperature 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 the fuel characteristics, engine operating conditions and test conditions are essentially the same throughout the test. Appendix E summarizes the assumptions and equations required for the calculations.

Results

Table 3 shows the overall performance factors for the fleet for the baseline and treated fuel tests at 1600 rpm. At 1600 rpm the improvement in fuel economy for the fleet was 9.6%.

Table 4 shows the overall performance factors for the fleet for the baseline and treated fuel tests at 1900 rpm. At 1900 rpm the improvement in fuel economy for the fleet was 7.4%. Of the six trucks originally selected to be tested, all of the trucks were available for the treated fuel portion of the evaluation. However, one truck in the test fleet showed an increase in hydrocarbon levels which suggested that the condition of the truck had changed or been altered sometine between the baseline and treated segment of the evaluation. However, even including this truck, the fleet average calculations results in a 7.4% improvement in fuel economy at 1900 rpm.

The average fuel economy improvement, at both rpm's, for the entire fleet was 8.5%.

Conclusions

The following conclusion may be made from the results of the FPC-1 evaluation conducted for R.E. Pierce:

* The addition of FPC-1 to the diesel fuel used by Pierce Trucking resulted in fuel economy improvements of 9.6% at 1600 rpm and 7.4% at 1900 rpm.

Table I

Trucks Used
Throughout FPC-1 Evaluation Tests

Unit No.	Type	Engine	Miles
68	Cummins	400	9,939
150	Cummins	350	4,303
153	Cummins	300	4,816
154	Cummins	350	3,950
155	Cummins	350	3,991
445	Detroit	435	6,680

Table II

Summary of Exhaust Measurements During Baseline and Treated Fuel Tests

Engine Speed	CO2 Vol%	CO Vol%	O2 Vol%	HC ppm	Exhaust Temp
1600					
Base	1.71	0.028	18.9	13.9	318 F
Treated	1.56	0.028	18.4	21.9	323 F
1900					
Base	1.96	0.033	18.6	15.6	339 F
Treated	1.82	0.030	18.1	23.2	339 F

21.9 ↑

?

Table III

Volume Fractions and Performance Factor
1600 R.P.M.

	Baseline	Treated
VFCO	0.000283	0.000280
VFHC	0.00001397	0.0000219
VFCO2	0.0171	0.0156
VFO2	0.1894	0.1840

Mwt1	29.0320	Mwt2	28.9869
pf1	353227.8930	pf2	384694. 9782
PF1	209779.6189	PF2	229994.7381

$$229994.7381 - 209779.6189 = \frac{20{,}215.1192}{209779.6189} \times 100 = 9.6\%$$

Table IV

Volume Fractions and Performance Factor
1900 R.P.M.

	Baseline	Treated	
VfCO	0.000331	0.000300	
VFHC	0.00001555	0.00002190	← .0000232 ?
VFCO2	0.0196	0.0182	
VFO2	0.1864	0.1811	

Mwt1	29.0601	Mwt2	29.0169
pf1	308413.5494	pf2	330952.4258
PF1	127005.9714	PF2	136338.7519

$$136338.7519 - 127005.9714 = \frac{9332.7805}{127005.9714} \times 100 = 7.4\%$$

BASE – BLACK
TREATED – RED

R.E. PIERCE TRUCKING

# 68	CO	HC	CO_2	O_2	Temp	P.F.
1900	.0003	.0000142	.0187	.1864	344.8	216,913.7
1900 (circled in red)	.0003	.000014	.01804	.1824	341.8	223,655.2
✗ 1600	.0003	.0000142	.01626	.1908	318.2	282,715.3
1600 (circled in red)	.0003	.0000166	.01554	.1836	326.4	297,917.4

# 150	CO	HC	CO_2	O_2	Temp	P.F.
1900	.0003	.0000094	.02128	.1848	354.6	193,909.0
1900 (circled in red)	.0003	.0000124	.01974	.1798	359	209,380.2
1600	.0003	.0000092	.01832	.1878	331.8	256,588.1
1600 (circled in red)	.0003	.000015	.01696	.1822	348.2	281,461.4

# 153	CO	HC	CO_2	O_2	Temp	P.F.
1900	.0002	.00000975	.019325	.1895	353	213,721.1
1900 (circled in red)	.0002	.0000102	.01832	.1816	345.2	222,720.6
1600	.0002	.0000096	.0173	.1898	331.8	272,840.0
1600 (circled in red)	.0002	.0000132	.01596	.1838	328	293,102.9

Pierce

#154	CO	HC	CO_2	O_2	Temp	P.F.
1900	.00052	.0000324	.02242	.1812	379.8	186,961.9
1900	.00054	.0000646	.02	.1776	372	204,330.5
1600	.0004	.0000266	.0192	.1858	354	249,325.9
1600	.00042	.0000496	.0173	.1816	351.6	272,121.7

#155	CO	HC	CO_2	O_2	Temp	P.F.
1900	.00044	.0000186	.01932	.1872	323.2	202,824.1
1900	.0003	.0000278	.01764	.1812	318	220,706.3
1600	.0003	.000015	.01688	.1896	307.8	268,892.6
1600	.0002	.0000232	.01536	.1844	315.2	298,153.7

#445	CO	HC	CO_2	O_2	Temp	P.F.
1900	.0002	.0000078	.01662	.19	280.8	225,787.3
1900	.0002	.0000102	.01536	.184	299.2	249,458.3
1600	.0002	.000009	.01438	.1924	264.4	299,104.7
1600	.00024	.0000138	.01248	.1886	270	343,960.1

Wrong!

Compare with yellow sheets by Kim

FLEET	CO	HC	CO_2	O_2	Temp	P.F.
1900	.000326	.0000153	.01961	.18651	339.3	205,397.8
1900	.000306	.0000232	.01818	.1811	339.2	220,482.8
1600	.000283	.0000139	.01705	.1893	318.0	270,191.6
1600	.000276	.0000219	.0156	.1840	323.2	295,459.1

avg. 271,577

FUEL PERCENT INCREASE

TRUCK #	RPM 1900	RPM 1600
68	3.10%	5.37%
150	7.97	9.69
153	4.21	7.42
154	9.28	9.14
155	8.81	10.88
445	10.48	14.99

FLEET AT-1900 RPM = 7.34%

AT-1600 RPM = 9.35%