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AN EVALUATION OF FPC-1 FUEL PERFORMANCE CATALYST

BY

WAYNE W. SELL CORPORATION
SARVER, PENNSYLVANIA

REPORT PREPARED BY:

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PROVO, UTAH

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UHI CORPORATION

AND

RESEARCH DEVELOPMENT PRODUCTS INC.

UHI TECHNICAL REPORT

Abstract

A test program to determine the effect of FPC-1 fuel catalyst on the fuel economy of the Wayne W. Sell Corporation fleet of trucks, in Sarver, Pennsylvania, was conducted under the direction of Ed Nusser with RDP Inc., and Ed Funk, with Wayne W. Sell Corporation. 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 a minimum cost savings of 5.4% for the diesel fleet which was evaluated.

Introduction

This report summarizes the results of field tests conducted on Wayne W. Sell Corporation 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 CO2, 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 CO2, 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 Wayne W. Sell Corporation was selected for the FPC-1 evaluation. Table I shows the engine and mileage of the five 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, except for unit no. 208, which was not available for 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 II, and the actual measurements are contained in Appendix C.

After the baseline test, on October 21, 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 7617 miles per truck when, on November 21,1987, the fuel consumption test described above was repeated for each truck. The measurements for the trucks with treated fuel are also summarized in Table II, 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 III shows the overall performance factors for the fleet for the baseline and treated fuel tests at 1600 rpm. At 1600 rpm the minimum improvement in fuel economy for the fleet was 5.1%. It should be noted, that all tests were conducted under a no-load condition which only shows minimum fuel economy improvements. Under loaded conditions, consistent improvements of up to 5%, above no load conditions,can be expected.

Table IV shows the overall performance factors for the fleet for the baseline and treated fuel tests at 1900 rpm. At 1900 rpm the minimum improvement in fuel economy for the fleet was 5.4%. Of the six trucks originally selected to be tested, all of the trucks were available for the treated fuel portion of the evaluation,except for unit no. 208.

The average minimum fuel economy improvement, at both rpm's, for the entire fleet was 5.25%.

Further, the inline particulate filter showed a marked reduction in solid particulates during the treated segment of the evaluation. This is important to note since the filter was accessed to the exhaust stream for only 41 minutes during the baseline segment as compared to 45 minutes for the treated segment of the evaluation. Photograph comparisons of the baseline, as well as treated filters are attached under the heading entitled **Conclusions.**

Conclusions

The following conclusion may be made from the results of the FPC-1 evaluation conducted for Wayne W. Sell Corporation:

* The addition of FPC-1 to the diesel fuel used by Wayne W. Sell Corp. resulted in minimum fuel economy improvements of 5.1% at 1600 rpm and 5.4% at 1900 rpm.

* The particulate filter used during the baseline and treated segment of the evaluation clearly showed that the test fleet was running cleaner during the treated segment of the evaluation.

Baseline Treated

Table I

Trucks Used
Throughout FPC-1 Evaluation Tests

Unit No.	Type	Engine	Miles
167	Cummins	350	5,272
211	Mack	285	9,154
216	Mack	350	6,987
218	Cummins	350	10,998
220	Mack	300	5,673

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	1.90	0.052	18.8	17.9	310.2 F
Treated	1.82	0.051	18.8	13.2	315.3 F
1900					
Base	2.32	0.048	18.3	12.9	344.6 F
Treated	2.18	0.048	18.4	11.3	337.9 F

Table III

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

	Baseline	Treated
VFCO	0.000517	0.000512
VFHC	0.0000179	0.00001324
VFCO2	0.0190	0.0182
VFO2	0.1875	0.1877

Mwt1	29.0550	Mwt2	29.0428
pf1	314635.3025	pf2	328456.2940
PF1	147314.3526	PF2	154803.7475

$$154803.7475 - 147314.3526 = \frac{7,489.3949}{147314.3526} \times 100 = 5.1\%$$

Table IV

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

	Baseline	Treated
VfCO	0.00048	0.000476
VFHC	0.00001297	0.00001128
VFCO2	0.0232	0.0218
VFO2	0.1832	0.1836

Mwt1	29.1048	Mwt2	29.0839
pf1	260357.5392	pf2	276639.0675
PF1	98813.0547	PF2	104118.0717

$$104118.0717 - 98813.0547 = \frac{5,305.0170}{98813.0547} \times 100 = 5.4\%$$

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EXHAUST GAS ANALYSIS FORM

NAME OF COMPANY Wayne Sell

DATE OF TEST Oct 21, 1987

TYPE OF EQUIPMENT TESTED

ENGINE TYPE AND SPECS 350 Cum

I.D. NUMBER 167 MILEAGE (OR HOURS) 193,295

TYPE OF TEST

AMBIENT AIR TEMPERATURE

EXHAUST READINGS

	CO	HC	CO_2	O_2	EX. TEMP.	RPM
1.	.04	15	2.10 ~~2.05~~	18.5	410	1900
2.	.04	17	2.05	18.4	408	1900
3.	.04	19	2.05	18.5	408	1900
4.	.04	22	2.05	18.6	408	1900
5.	.04	24	2.07	18.7	409	1900
6.	.04	36	1.64	19.2	362	1600
7.	.04	37	1.63	19.0	361	1600
8.	.04	42	1.65	19.0	355	1600
9.	.04	42	1.64	18.9	354	1600
10.	.04	46	1.65	19.1	350	1600

START TIME: 4:48 END TIME: 4:56 LENGTH OF TEST: 8

Signature of technicians

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EXHAUST GAS ANALYSIS FORM

NAME OF COMPANY WAYNE SELL

DATE OF TEST OCT 21, 1987

TYPE OF EQUIPMENT TESTED

ENGINE TYPE AND SPECS 285 MACK

I.D. NUMBER 211 MILEAGE (OR HOURS) 230,988

TYPE OF TEST

AMBIENT AIR TEMPERATURE

EXHAUST READINGS

	CO	HC	CO_2	O_2	EX. TEMP.	RPM
1.	.03	5	2.47	18.2	363	1900
2.	.02	4	2.47	18.1	363	1900
3.	.02	5	2.46	18.3	363	1900
4.	.02	5	2.46	18.3	363	1900
5.	.02	6	2.46	18.1	363	1900
6.	.02	8	2.06	18.7	329	1600
7.	.02	8	2.05	18.7	328	1600
8.	.02	7	2.06	18.7	325	1600
9.	.02	6	2.06	18.7	324	1600
10.	.02	6	2.05	18.5	323	1600

START TIME: 4:26 END TIME: 4:31 LENGTH OF TEST: 5

Signature of technicians

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EXHAUST GAS ANALYSIS FORM

NAME OF COMPANY WAYNE SELL

DATE OF TEST OCT 21 1987

TYPE OF EQUIPMENT TESTED

ENGINE TYPE AND SPECS 350 MACK

I.D. NUMBER 216 MILEAGE (OR HOURS) 246,780

TYPE OF TEST

AMBIENT AIR TEMPERATURE 44

EXHAUST READINGS

	CO	HC	CO_2	O_2	EX. TEMP.	RPM
1.	.08	10	2.50	18.0	254	1900
2.	.08	10	2.50	18.0	257	1900
3.	.08	10	2.49	18.1	260	1900
4.	.08	10	2.49	18.1	265	1900
5.	.08	10	2.48	18.1	267	1900
6.	.09	13	1.98	18.7	235	1600
7.	.09	13	1.97	18.6	236	1600
8.	.09	13	1.97	18.7	232	1600
9.	.09	13	1.97	18.6	233	1600
10.	.09	13	1.98	18.7	233	1600

START TIME: 4:03 END TIME: 4:09 LENGTH OF TEST: 6

Signature of Technicians

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RIGHT SIDE

EXHAUST GAS ANALYSIS FORM

NAME OF COMPANY Wayne Sell

DATE OF TEST Oct 21 1987

TYPE OF EQUIPMENT TESTED

ENGINE TYPE AND SPECS 350 cum

I.D. NUMBER 218 MILEAGE (OR HOURS) 22772

TYPE OF TEST

AMBIENT AIR TEMPERATURE

EXHAUST READINGS

	CO	HC	CO_2	O_2	EX. TEMP.	RPM
1.	.04	24	1.99	18.7	323	1900
2.	.03	24	1.98	18.7	327	1900
3.	.03	24	1.98	18.8	332	1900
4.	.03	24	1.98	18.8	332	1900
5.	.03	24	1.97	18.8	336	1900
6.	.03	22	1.68	19.0	317	1600
7.	.03	22	1.68	18.9	317	1600
8.	.03	19	1.67	19.1	316	1600
9.	.03	19	1.67	19.0	316	1600
10.	.03	19	1.67	18.9	315	1600

START TIME: 4:59 END TIME: 5:08 LENGTH OF TEST: 9

Signature of technicians

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EXHAUST GAS ANALYSIS FORM

NAME OF COMPANY Wayne W. Sell Corp.

DATE OF TEST 21-Oct-87

TYPE OF EQUIPMENT TESTED Mack

ENGINE TYPE AND SPECS 300

I.D. NUMBER 220 MILEAGE (OR HOURS) 296991

TYPE OF TEST

AMBIENT AIR TEMPERATURE

EXHAUST READINGS

	CO	HC	CO_2	O_2	EX. TEMP.	RPM
1.	.09	14	2.40	18.3	316	1900
2.	.09	14	2.39	18.1	317	1900
3.	.10	15	2.41	18.2	321	1900
4.	.10	15	2.41	18.1	322	1900
5.	.10	16	2.37	18.3	323	1900
6.	.11	17	1.97	18.7	291	1600
7.	.11	18	1.97	18.6	290	1600
8.	.11	19	1.99	18.6	287	1600
9.	.11	19	2.00	18.5	287	1600
10.	.11	18	1.98	18.6	285	1600

START TIME: 4:36 END TIME: 4:43 LENGTH OF TEST: 7

Signature of technicians

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EXHAUST GAS ANALYSIS FORM

NAME OF COMPANY WAYNE SELL

DATE OF TEST NOV 21, 1987

TYPE OF EQUIPMENT TESTED

ENGINE TYPE AND SPECS 350 cum

I.D. NUMBER 167 MILEAGE (OR HOURS) 198,567

TYPE OF TEST

AMBIENT AIR TEMPERATURE 40

EXHAUST READINGS

	CO	HC	CO_2	O_2	EX. TEMP.	RPM
1.	.02	9	2.00	18.5	392	1900
2.	.02	8	1.99	18.6	393	1900
3.	.02	9	1.97	18.6	395	1900
4.	.02	8	1.98	18.7	395	1900
5.	.02	9	1.97	18.6	396	1900
6.	.03	10	1.58	19.1	360	1600
7.	.03	10	1.58	19.0	359	1600
8.	.03	10	1.57	19.1	358	1600
9.	.03	9	1.56	19.2	358	1600
10.	.03	10	1.57	19.1	356	1600

START TIME: 12:27 END TIME: 12:39 LENGTH OF TEST: 12

Signature of technicians

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EXHAUST GAS ANALYSIS FORM

NAME OF COMPANY WAYNE SELL

DATE OF TEST NOV. 19, 1987

TYPE OF EQUIPMENT TESTED

ENGINE TYPE AND SPECS 285 MACK

I.D. NUMBER 211 MILEAGE (OR HOURS) 240,142

TYPE OF TEST

AMBIENT AIR TEMPERATURE

EXHAUST READINGS

	CO	HC	CO_2	O_2	EX. TEMP.	RPM
1.	.02	12	2.36	18.3	351	1900
2.	.03	12	2.35	18.2	351	1900
3.	.03	10	2.35	18.4	352	1900
4.	.03	10	2.34	18.3	354	1900
5.	.03	13	2.34	18.4	357	1900
6.	.03	13	1.98	18.7	333	1600
7.	.03	13	1.98	18.6	332	1600
8.	.03	13	1.98	18.8	328	1600
9.	.03	13	1.98	18.6	327	1600
10.	.03	13	1.98	18.7	325	1600

START TIME: 3:51 END TIME: 4:02 LENGTH OF TEST: 9

Signature of technicians A. Tauscher

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EXHAUST GAS ANALYSIS FORM

NAME OF COMPANY WAYNE SELL

DATE OF TEST NOV. 19, 1987

TYPE OF EQUIPMENT TESTED

ENGINE TYPE AND SPECS 350 MACK

I.D. NUMBER 216 MILEAGE (OR HOURS) 253767

TYPE OF TEST

AMBIENT AIR TEMPERATURE

EXHAUST READINGS

	CO	HC	CO_2	O_2	EX. TEMP.	RPM
1.	.09	13	2.41	17.9	283	1900
2.	.08	13	2.42	17.8	286	1900
3.	.08	14	2.36	18.0	293	1900
4.	.08	14	2.36	17.8	296	1900
5.	.07	14	2.40	17.9	299	1900
6.	.08	17	1.92	18.4	271	1600
7.	.08	18	1.93	18.5	270	1600
8.	.08	18	1.91	18.6	269	1600
9.	.09	18	1.90	18.7	269	1600
10.	.09	18	1.91	18.5	268	1600

START TIME: 6:10 END TIME: 6:18 LENGTH OF TEST: 8

Signature of technicians

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EXHAUST GAS ANALYSIS FORM

NAME OF COMPANY WAYNE SELL

DATE OF TEST NOV 21, 1987

TYPE OF EQUIPMENT TESTED

ENGINE TYPE AND SPECS 350 GUM

I.D. NUMBER 218 MILEAGE (OR HOURS) 33,770

TYPE OF TEST

AMBIENT AIR TEMPERATURE

EXHAUST READINGS

	CO	HC	CO_2	O_2	EX. TEMP.	RPM
1.	.03	7	1.91	18.8	335	1900
2.	.03	6	1.90	18.8	336	1900
3.	.03	8	1.90	18.7	337	1900
4.	.03	8	1.91	18.8	338	1900
5.	.03	9	1.90	18.8	342	1900
6.	.02	10	1.63	18.9	326	1600
7.	.02	10	1.63	19.0	326	1600
8.	.03	9	1.64	19.1	326	1600
9.	.02	9	1.62	19.0	325	1600
10.	.02	9	1.62	19.0	325	1600

START TIME: 12:49 END TIME: 12:57 LENGTH OF TEST: 8

Signature of technicians

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DRIVER - DOESN'T SMOKE AS MUCH AS BEFORE

EXHAUST GAS ANALYSIS FORM

NAME OF COMPANY WAYNE SELL

DATE OF TEST NOV 19, 1987

TYPE OF EQUIPMENT TESTED

ENGINE TYPE AND SPECS 300 MACK

I.D. NUMBER 220 MILEAGE (OR HOURS) 302 644

TYPE OF TEST

AMBIENT AIR TEMPERATURE

EXHAUST READINGS

	CO	HC	CO_2	O_2	EX. TEMP.	RPM
1.	.08	17	2.29	18.3	312	1900
2.	.08	17	2.29	18.0	312	1900
3.	.08	14	2.29	18.3	314	1900
4.	.08	14	2.28	18.0	314	1900
5.	.08	14	2.27	18.4	315	1900
6.	.9	15	2.03	18.7	296	1600
7.	.9	15	2.03	18.3	295	1600
8.	.9	17	2.02	18.8	294	1600
9.	.9	17	2.02	18.3	294	1600
10.	.9	17	2.02	18.5	292	1600

START TIME: 3:04 END TIME: 3:12 LENGTH OF TEST: 8

Signature of technicians B Lash