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EVALUATION OF FPC-1 FUEL PERFORMANCE CATALYST

AT

THREE RIVERS ICE CREAM

REPORT PREPARED BY
U.H.I. CORPORATION
PROVO, UTAH

ED J. NUSSER
EASTERN REGION SALES MANAGER
EVANS CITY, PA

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Abstract

This paper will discuss the effect of an iron based fuel catalyst (ferrous picrate) upon fuel economy and exhaust gas emissions in a fleet of diesel powered trucks operated by Three Rivers Ice Cream. It will be shown that the catalyst can provide significant cost savings to the diesel fleet operated by Three Rivers Ice Cream. It will also be shown that a test method that measures changes in the carbon containing gases in the exhaust stream is an accurate means of determining changes in fuel flow to the engine.

Introduction

An aftermarket combustion improver called Fuel Performance Catalyst - 1 (FPC-1) contains an iron based catalyst (ferrous picrate) that has undergone extensive testing in EPA recognized independent and university affiliated laboratories. These tests, in both gasoline and diesel powered passenger vehicles, have demonstrated that the catalyst can provide fuel savings of 2% to 10%, depending upon vehicle operating parameters, fuel quality, equipment condition, vehicle age and engine mileage.

Test procedures have included the EPA standardized Federal Test Procedures (FTP) and Highway Fuel Economy Test (HFET), the SAE J-1082 Suburban and Interstate Test Cycles, CRC cold start driveability test, and a computerized engine dynamometer test sequence.

Field testing, primarily in heavy duty diesel fleets, substantiates laboratory findings with even greater average improvements and also reveals the catalyst can be an effective means of further reducing operating costs by inhibiting the buildup of hard carbon deposits on critical engine components.

This report summarizes the results of the Three Rivers test of the effect of FPC-1 on fuel economy in it's fleet of diesel powered trucks.

Measurement of Fuel Economy

Carbon Balance vs Direct Measurement

Until late 1973, vehicle fuel economy had been determined primarily by using various test track or road test procedures. In September 1973, the U.S. Environmental Protection Agency (EPA) introduced a method of determining vehicle fuel economy in conjunction with its chassis dynamometer emissions test. This method determines fuel consumption based upon vehicle exhaust emissions through a "carbon balance" calculation rather than a direct measurement of fuel consumed.

Starting in 1974, the carbon balance method was used solely in the EPA, CVS cold start emissions test cycle (LA-4 Cycle). In 1975, the cycle was modified adding a hot start (FTP). Later, a highway test was also developed (HFET).

A series of tests done by Ford Motor Company compared the traditional fuel measurement techniques (volumetric or gravimetric) to the carbon balance method. The results, published in SAE Technical Paper Series 75002 (Exhibit A) entitled " Improving the Measurement of Chassis Dynamometer Fuel Economy", confirmed;

> "... 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 Ford Motor study determined that the most important factors in the measurement of fuel consumption with the carbon balance method are:

- For fuel consumption, the measurement of CO_2
- For distance traveled, the dynamometer to vehicle interface conditions, precision and manner in which the vehicle is driven.
- Use of standardized test equipment and procedures, calibration and ambient condition correction methods.

The exhaust gas analysis/carbon balance method of determining fuel consumption changes used by UHI personnel uses a state-of-the-art, non-dispersive infrared (NDIR) exhaust gas analyzer made by Sun Electric Corporation to measure CO_2 and other carbon containing exhaust gases. The Sun Electric SGA-9000 Exhaust Gas Analyzer is approved by the EPA for vehicle emissions analysis. The SGA-9000 is calibrated internally using Scott Calibration Gases as recommended by Sun Electric. Specifications for the SGA-9000 are found in Exhibit B.

The method used by UHI does not require the vehicle to travel any distance, nor does the vehicle interface with a chassis dynamometer during testing. Consequently, inaccuracies created by improper dynamometer to vehicle interfacing and errors in driving do not occur. Additionally, a miles per gallon figure is not computed since no mileage is accumulated. The method measures fuel flow to the engine at a specified load and rpm, and makes comparisons on a percentage basis between the consumption of control fuel (not treated with FPC-1) and the consumption of FPC-1 treated fuel at that load.

Although not as controlled as an EPA laboratory test, the carbon balance method utilized by UHI is the most accurate and practical means of measuring fuel consumption changes in the field. Additionally, the carbon balance method has consistently proven to be more accurate than monthly mpg fleet records.

The technique measures exhaust concentrations of carbon dioxide (CO_2), carbon monoxide (CO), oxygen (O_2), and unburned hydrocarbons (HC). Exhaust gas temperature is also measured and engine load is determined from engine tachometer readings.

Methodology

A fleet of diesel powered trucks owned and operated by Three Rivers Ice Cream, was selected as the test fleet.

After calibrating the SGA-9000 analyzer and the IMC thermocouple, and performing a leak test on the sampling hose and connections, each truck engine was brought up to stable operating temperature as verified with engine water temperature and exhaust temperature. No exhaust data was recorded until each truck engine had stabilized.

The fleet was first tested, operating at 1900 rpm, followed by a test at 1600 rpm. Readings of CO2, CO, HC (measured as CH4), O2 and exhaust temperature were taken at approximately 30 second intervals.

After recording the first two readings, the SGA-9000 auto calibrating button was depressed and the instrument "checked itself" to prevent any drift. This self checking procedure was repeated after each set of two data points throughout the entire 1900 and 1600 rpm test. Several readings were taken on each truck and at each rpm. The data sheets are enclosed in Exhibit C.

After control testing, the fuel used by the Three Rivers fleet was treated with FPC-1 at the recommended 1 to 5000 ratio (1 oz. FPC-1 to 40 gallons diesel). This took place near the 25th of June, 1988.

On September 3, 1988 the above procedure was repeated. The treated fuel data sheets are attached in Exhibit D.

All fuel used during the baseline and treated test segments was #2 diesel.

Special Notes:

1.) The test procedure calls for a sequence of rpm testing at 1900 and 1600 rpm, on the same equipment, to show that the change in fuel flow between the two loads can be demonstrated with the SGA-9000 Exhaust Gas Analyzer. It is obvious that a drop in fuel consumption will occur when reducing rpm from 1900 to 1600 and it shows up readily during the baseline test. This validates the concept of fuel flow measurement with exhaust gas analysis.

2.) The 1900 rpm load is more indicative of actual engine operation and improvements at this rpm are more meaningful.

3.) A qualitative technique for determining reductions in smoke and particulate was performed during both control and treated fuel test segments. This was done by attaching a new 25 micron filter to the SGA-9000 sampling hose at the beginning of each test segment. The filter traps unburned fuel that is exhausted from the engine as particulate or soot. A comparison of the control fuel and treated fuel filters revealed that the fuel was burning much cleaner with FPC-1 as particulate volume was visibly reduced in the treated filter. The control test segment involved thirty-six minutes of sampling on the trucks; the treated segment included forty-seven minutes of particulate sampling. A photograph of the two filter traps is found under Appendix F.

Equipment List

Unit #	Make	Engine	Mileage
D40	Mack	237	198,683
D41	IH	225,423	
D42	IH	93,084	

Summary

The data from the 1900 rpm test control and treated fuel are summarized on Tables 1-3. The data from the 1600 rpm tests are summarized on Tables 4-6. All treated exhaust temperatures have been corrected for a 14 degree lower ambient temperature recorded during the treated fuel test segment.

Table 1.

Summary of Exhaust Gas Data at 1900 RPM

Truck D40

	CO	HC	CO2	O2	Exh. Temp.
Control	0.01%	10.60ppm	2.21%	17.28%	373.60 *F
Treated	0.01%	9.2ppm	2.06%	18.04%	360.20 *F

Table 2.

Summary of Exhaust Gas Data at 1900 RPM

Truck D41

	CO	HC	CO2	O2	Exh. Temp.
Control	0.01%	8.4ppm	1.61%	18.12%	276.6 *F
Treated	0.01%	9.2ppm	1.54%	18.46%	305.0 *F

Table 3.

Summary of Exhaust Gas Data at 1900 RPM

Truck D42

	CO	HC	CO2	O2	Exh. Temp.
Control	0.01%	10ppm	1.50%	18.34%	290.4 *F
Treated	0.012%	6ppm	1.42%	18.58%	297.4 *F

Table 4.

Summary of Exhaust Gas Data at 1600 RPM

Truck D40

	CO	HC	CO2	O2	Exh. Temp.
Control	0.01%	14ppm	1.84%	17.78%	338.8 *F
Treated	0.01%	13ppm	1.74%	18.46%	333.8 *F

Table 5.

Summary of Exhaust Gas Data at 1600 RPM

Truck D41

	CO	HC	CO2	O2	Exh. Temp.
Control	0.01%	12ppm	1.33%	18.45%	271.8 *F
Treated	0.01%	9.8ppm	1.28%	18.76%	304.8 *F

Table 6.

Summary of Exhaust Gas Data at 1600 RPM

Truck D42

	CO	HC	CO2	O2	Exh. Temp.
Control	0.01%	9.6ppm	1.33%	18.58%	275.8 *F
Treated	0.01%	7ppm	1.28%	18.94%	286.8 *F

From the above data volume fractions can be easily calculated and weighed using the known molecular weight of each gas. A total molecular weight and engine performance factors can then be calculated from which fuel consumption changes can be determined. The volume fractions, total molecular weight and engine performance factors for each truck at 1900 rpm are found on Tables 7-9. The same for the 1600 rpm data is found on Tables 10-12. The engineering formulae from which these are calculated are found in Exhibit E.

Table 7

Volume Fractions for the 1900 RPM Data

<u>Truck D40</u>

	Control	Treated
VfCO	0.0001	0.0001
VfHC	0.0000106	0.0000092
VfCO2	0.0221	0.0206
VfO2	0.1728	0.1804

Total Molecular Weight and Performance Factors

Mwt1	29.0454	**Mwt2**	29.0517
pf1	277268.6941	**pf2**	297485.9827
PF1	180571.2370	**PF2**	190623.4398

Percent Change in Fuel Flow

190623.4398 - 180571.2370 = 10052.2028

$$\frac{10052.2028}{1870571.2370} \times 100 = +\ 5.57\%$$

Table 8

Volume Fractions for the 1900 RPM Data

Truck D41

	Control	Treated
VfCO	0.0001	0.0001
VfHC	0.0000084	0.0000092
VfCO2	0.0161	0.0154
VfO2	0.1812	0.1846

Total Molecular Weight and Performance Factors

Mwt1	28.9829	**Mwt2**	28.9853
pf1	379046.8072	**pf2**	396015.1106
PF1	218129.5923	**PF2**	236680.9059

Percent Change in Fuel Consumption

$$236680.9059 - 218129.5923 = 18551.3136$$

$$\frac{18551.3136}{218129.5923} \times 100 = 8.5\%$$

Table 9

Volume Fractions for the 1900 RPM Data

Truck D42

	Control	Treated
VfCO	0.0001	0.00012
VfHC	0.000010	0.000006
VfCO2	0.0150	0.0142
VfO2	0.1834	0.1858

Total Molecular Weight and Performance Factors

Mwt1	28.9742	**Mwt2**	28.9707
pf1	406177.0075	**pf2**	429492.0701
PF1	238121.2706	**PF2**	254138.5109

Percent Change in Fuel Flow

254138.5109 - 238121.2706 = 16017.2403

160176.2403
238121.2706 x 100 = + 6.73%

Table 10

Volume Fractions for the 1600 RPM Data

<u>Truck D40</u>

	Control	Treated
VfCO	0.0001	0.0001
VfHC	0.000014	0.000013
VfCO2	0.0184	0.0174
VfO2	0.1778	0.1846

Total Molecular Weight and Performance Factors

Mwt1	29.0064	**Mwt2**	29.0176
pf1	331703.7683	**pf2**	350823.0157
PF1	230404.3218	**PF2**	239108.7650

Percent Change in Fuel Flow

$$239108.7650 - 230404.3218 = 8704.4432$$

$$\frac{8704.4432}{230404.3218} \times 100 = +3.78\%$$

Table 11

Volume Fractions for the 1900 RPM Data

Truck D41

	Control		**Treated**
VfCO	0.0001		0.0001
VfHC	0.000012		0.0000098
VfCO2	0.0133		0.0128
VfO2	0.1845		0.1876

Total Molecular Weight and Performance Factors

Mwt1	28.9515	**Mwt2**	28.9558
pf1	456691.6810	**pf2**	474860.0743
PF1	290614.7584	**PF2**	314728.9988

Percent Change in Fuel Consumption

314728.9988 - 290714.7584 = 24014.2404

$$\frac{24014.2404}{290614.7584} \times 100 = 8.26\%$$

Table 12

Volume Fractions for the 1600 RPM Data

Truck D42

	Control	Treated
VfCO	0.0001	0.0001
VfHC	0.0000096	0.000007
VfCO2	0.0133	0.0128
VfO2	0.1858	0.1894

Total Molecular Weight and Performance Factors

Mwt1	28.9566	**Mwt2**	28.9628
pf1	457275.8010	**pf2**	475611.6660
PF1	292576.9864	**PF2**	308858.0802

Percent Change in Fuel Flow

$$308858.0802 - 292576.9864 = 16281.0938$$

$$\frac{16281.0938}{292576.9864} \times 100 = +5.56\%$$

Conclusion

Based upon the data gathered during exhaust gas testing with and without FPC-1 Fuel Performance Catalyst, the addition of FPC-1 to the fuel used by the Three Rivers Ice Cream test fleet created an average 6.93% reduction in fuel consumption at 1900 rpm and a 5.86% reduction in fuel consumption at 1600 rpm.

The qualitative filter trap analysis shows that the FPC-1 treated fuel burned cleaner as manifested by a marked reduction in particulate accumulation in the treated filter trap while sampling 30% longer (47 mins. vs 36 mins.).