FPC WORLDWIDE, LLC

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DOCKET	
08-ALT-1	
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By E-Mail and UPS

James D. Boyd, Vice Chair
Karen Douglas, Commissioner
California Energy Commission
Dockets Office, MS-4
AB118 Program
1516 Ninth Street
Sacramento, CA 95814-5512

Re: Docket No. 08-ALT-1

Dear Mr. Boyd and Ms. Douglas:

FPC® is a patented diesel performance catalyst that significantly reduces harmful emissions including greenhouse gas and particulate matter and significantly increases fuel efficiency on average by 4-8%. However, unlike all other fuel additive companies that routinely make such claims we support such claims with numerous tests conducted by universities, independent labs, and field tests using the most rigorous scientific fuel efficiency and emission reduction tests that exist. These tests include the EPA carbon mass balance test (AS 2077-1982) (the "Standard Federal Test Procedure" for fuel economy and emission testing); SAE tests; specific fuel consumption tests; and Bacharach and Bosch smoke tests. Summaries from many of those tests are quoted and available at our website www.fpcworldwide.com.

Indeed, FPC® has been so scientifically tested that based on the analysis of hundreds of these scientific tests, which include over 27,000 data points, Australia recently published the findings of its climate change industry advisers that small traces of FPC® significantly reduces greenhouse gases and increases fuel efficiency of in-service diesel engines by 5-9%. (See excerpt of that report, **Exhibit 1.**) In that report, Australia also published its industry advisers' recommendation that users of diesel fuel in its country begin using FPC® (called "FTC" there) because the effectiveness of FPC® has been scientifically "validated". Also, it is worth noting that Australia has awarded grants totaling $500,000 for scientific research to further the benefits from using FPC®, which amount was supplemented by BHP Billiton (a customer) in the amount of $250,000.

In accordance with the AB118 Investment Plan, we hereby request the State of California to fund any additional tests it deems necessary to consider and then to treat all diesel fuel used by your State with FPC®. Further, to the extent necessary, we request funds for any additional testing the Air Resources Board ("ARB") deems necessary to consider amending its recent rules for diesel off road and on road trucks to permit compliance with those rules by using FPC® instead of the far more expensive alternatives that are now permitted. Those amendments will save users substantial sums of monies and could save your State up to $1 billion in grants and loans to companies to assist them in complying with ARBs recently adopted emission regulations for heavy-duty diesel trucks.

Before providing a brief description of the remaining supporting documents that we have attached, we would like to explain why FPC® is unlike any other "fuel additives" the State's employees involved in either emission control or fuel purchases may have ever tested or heard about. To be sure other companies claim that their fuel additives increase fuel efficiency and reduce harmful emissions but their products are mere solvents. As a result, although they can assist in cleaning an engine of unburned fuel compounds that will increase the "engine efficiency," they do not alter the "chemical combustion efficiency" of the engine. Thus, when comparing the increased fuel efficiency based solely on a cleaner engine with the cost of the fuel additive most sophisticated purchasers consider purchasing fuel additives to be uneconomical.

However, unlike other fuel additives, FPC® not only cleans the engine (after several applications) which does increase the "engine efficiency", but FPC® also acts as a catalyst during the combustion process that causes the engine to burn the fuel more completely than it would otherwise, which is the reason why FPC® increases a diesel engine's "chemical combustion efficiency." To prove this fact, FPC® was submitted to the nationally recognized Southwest Research Institute ("SwRI") in 1992 to conduct a RP-503 test that cost several hundred thousand dollars. SwRI determined that FPC <u>actually</u> <u>increases</u> the fuel efficiency of a like <u>new</u> locomotive engine by 1.74% which SwRI deemed "significant", and at the same time did not injure the engine. (See **Exhibit 2.)**

The SwRI's finding is consistent with our claim that FPC® increases fuel efficiency of <u>in service vehicles</u> on average by 4-8% since FPC® provides a greater amount of increased "chemical combustion efficiency" with older and less efficient engines coupled with the increase in "engine efficiency" of those engines from the solvent that is included in FPC®. Indeed, the Australia's industry advisers expressly relied upon the SwRI report in their finding about the 5-9% increased fuel efficiency from using FPC® and their recommendation to use FPC®.

Exhibits 3, 4, 5, and 6 are additional scientific test reports on the effects from using FPC®. These reports are based on the use of the EPA carbon mass balance formula that measures greenhouse gas and other emissions and determines the change, if any, in the amount of emissions and fuel efficiency based solely on the application of any fuel additive. In **Exhibit 3**, the test at Tarong Coal showed that FPC® increased its fuel efficiency by 8.3% and had a corresponding estimated savings for just the one mine where the test was conducted of 3,980 tons of CO_2. In **Exhibit 4**, a test of ten trucks at Wesfarmers showed that FPC® increased their fuel efficiency by 7.3% with an estimated annual reduction of 3,799 tons of greenhouse gases. The reason for including the excerpt of the Wesfarmers annual report along with that report is that it shows that when FPC® was applied to the entire company's trucking fleet after this pilot test fuel consumption decreased by 9% and the company had already reduced its emissions of CO_2 in the amount of 1,730 tons at the time of the annual report. In **Exhibit 5,** the test of a fleet of trucks at BEC/Allwaste showed that FPC® reduced fuel consumption by 11.63% and due to the fact that "FPC-1 treated fuel combusted more completely than the standard diesel, [u]nburned hydrocarbons (measured in n-hexane) were reduced 22.2%." Further smoke density was reduced 23.9% after being treated with FPC®. In **Exhibit 6**, the test at BFI Holding showed that after treatment of FPC® the fleet averaged a 7.40% reduction in fuel consumed; smoke density was reduced approximately 18%; and carbon monoxide levels were reduced approximately 18.5%.

In **Exhibit 3**, the report noted the fact that "more complete combustion (from using FPC®) will translate to significant reduction over time in engine maintenance costs." To that end, "[m]aintenance benefits documented include reduced wear metal profiles in lubricating oil and reduced soot. Combustion and exhaust spaces become essentially free of any hard carbon with continuous catalyst use." (See Exhibit 3.) **Exhibit 7** is an oil analysis study conducted at FMC over a 2 year period to determine the actual amount of reduction in wear metals from using FPC®. That study was conducted after FMC found using FPC®) reduced its fuel consumption by 10.7% and smoke density by 16.3%. Those findings are in that report as well as the findings showing over the 2 year period FPC® reduced iron wear by 22% and copper wear by 40%. Finally, **Exhibit 8** is a flow chart that shows how all of these and other benefits from using FPC® are related.

In terms of safety, SwRI determined using the Caterpillar 1G2 Test (ASTM 509A) that there are no detrimental effects to the engine from using FPC®, including any effects that could cause increased wear or deposit problems. (See **Exhibit 2**.) The manufacturer of FPC® warrants that no injury to the engine will occur if used in accordance with its directions and in this regard, no user has ever claimed that using FPC® injured one of its engines. Further, the EPA has approved FPC® for safety.

In terms of cost, the manufacturer of FPC® warrants that the cost of FPC® will never exceed the customer's cost savings from just its increased fuel efficiency, and offers a rebate to satisfy its warranty. To date, no customer has ever filed for even a partial let alone a full rebate. Thus, the State can achieve substantial reductions in harmful emissions from its own substantial use of diesel fuel at no net cost to you.

We look forward to working with you so that you can reach the same conclusions that Australia has made. In so doing, your State can continue to take the lead in this country in its committed efforts to reduce harmful emissions and increase fuel efficiency of diesel engines.

Very truly yours,

Stephen M. Trattner

SMT:sms

Attachments

cc: Air Resources Board
(with attachments)
Shep Tullier
(with attachments)

SUMMARY OF

WEAR METALS DATA

FMC CORP./DRY VALLEY MINE

PREPARED BY
FPC TECHNOLOGY
BOISE,IDAHO

AND

RDI Construction, Inc.
SOUTH POINT, OHIO

December 16, 1994

I. INTRODUCTION

In June of 1993, FMC Corporations Dry Valley Mine began a field trial of FPC-1 Fuel Performance Catalyst. The trial was designed to determine the effect of the catalyst upon fuel consumption, smoke emissions, oil soot levels and subsequent wear metals reduction.

Fuel consumption testing was conducted first using the Carbon Mass Balance Technique with the equipment operating under steady-state engine conditions. Fuel consumption for the fleet tested was reduced on average by 10.7%. The following table shows the equipment tested and the percentage fuel consumption reduction for each individual piece of equipment:

Unit	Type	Engine	RPM	%Change Fuel Consumption
204	CAT785 Haul Truck	3512	1800	-9.93
202	CAT785 Haul Truck	3512	1800	-7.98
201	CAT785 Haul Truck	3512	1800	-14.15

Smoke density was also measured during the fuel consumption test using the Bacharach Smoke Spot Method. Again, under steady-state engine conditions, smoke density was reduced 16.3% after FPC-1 fuel treatment. This was consistent with the observations of technicians and operators who indicated that smoke was less dents and lighter colored after treatment with FPC-1.

II. Oil Analysis Study

The oil analysis required a much longer period of time, and is still underway. However, data compiled between the mid-summer or late fall of 1992 and December of 1994 indicates a definite overall reduction in wear metals and therefore engine wear.

The oil analysis was extended to include the following pieces of equipment:

Unit#	Unit Type/Engine
101	P&H 2250 Shovel/CAT 3516
201	CAT 785 Haul Truck/3512
202	CAT 785 Haul Truck/3512
203	CAT 785 Haul Truck/3512
204	CAT 785 Haul Truck/3512
301	Cummins TD25G
303	CAT D10N
351	Dresser 970 RTD/VTA28C 1710 Cummins

The oil sample data provided begins in July 1992 and the analysis is being performed by Western States Caterpillar on samples drawn approximately every 250 hours of operation. The baseline oil sample data (untreated fuel) covers approximately 1,500 – 2,000 hours of equipment operation (7/92 – 6/93). The treated data covers a period of approximately 4,000 hours of equipment operation (7/93 – 12/94).

Prior oil analysis studies indicate soot and wear metals increase for a short period of time after initial FPC-1 treatment. Wear metals did appear to increase briefly in some equipment immediately after treatment but then began to trend lower and in most cases continued to trend lower (See Table 1).

Of particular note is the effect of FPC-1 upon the rate of engine wear. The rate of engine wear can be calculated from the relationship between total iron in the oil sample (parts per million iron) and the number of hours the engine operated on the oil change when the oil sample was taken. The simple calculation reveals a parts per million iron per hour of engine operation (Fe ppm/hr). Table 1 below summarizes the wear rate data in terms of iron wear per hour of operation, and calculates a percent change over the base fuel:

Table 1: Average rate of Iron Wear/Hour
(Fe ppm/hr)

Unit No.	Base Fuel	Treated Fuel 1	%Change	Treated Fuel 2	%Change
101	.074	.058	-21.6	.057	-23.0
201	.107	.099	-7.5	.096	-10.3
202	.144	.100	-30.6	.094	-34.7
203	.105	.090	-14.3	.091	-13.3
204	.152	.097	-36.2	.095	-37.5
301	.082	.046	-43.9	.045	-45.1
303	.115	.101	-12.2	.101	-12.2
351	.076	.081	-6.6	.083	-9.2
AVG.	**.107**	**.084**	**-21.5%**	**.083**	**-22.4%**

Notes:

(1) Average of all data collected after FPC-1 treatment occurred in 6/93.

(2) Same as (1) except first approximately 500 hours of operation after treatment excluded as this is considered carbon cleanup period.

Oil analysis studies conducted earlier reveal FPC-1 generally reduces soot mass in the motor oil over the same oil change interval, and also soot particle size. The reduced mass and particle size would reduce abrasion and slow viscosity change. Although soot levels generally did not decrease in this case, soot particle size evidently did as evidenced by the significant reduction in iron wear metal levels. The fact that soot levels did not materially change may be due to the fact that this equipment, in most cases, was a new fleet (approx. 2000 hours of equipment operation) at the commencement of this test. Soot levels in 5 of the 8 pieces of equipment appeared to be trending upward at the beginning of the test and may well have reached higher levels still without treatment with FPC-1.

A similar comparison was made on copper (Cu) wear metal levels. The data appears to be less consistent than the iron wear metals and there were several major “spikes” that occurred in several pieces of equipment both before and after treatment with FPC-1 (See data summary tables in Appendices). These spikes were removed fro the averages for a more valid comparison. The data in Table 2 below makes this comparison:

Table 2: Average Rate of Copper Wear/Hour
(CU ppm/hr)

Unit No.	Base Fuel	Treated Fuel(1)	%Change	Treated Fuel(2)	%Change
101	.031	.018	-41.9	.017	-45.2
201	.130	.065	-50.0	.063	-51.5
202	.027	.018	-33.3	.017	-37.0
203	.063	.047	-25.4	.047	-25.4
204	(3)	.039	(3)	.039	(3)
301	.009	.005	-44.4	.005	-44.4
303	.007	.012	71.4	.012	71.4
351	.024	.022	-8.3	.020	-16.7
Avg.	**.042**	**.028**	**-40.5%**	**.028**	**-40.5%**

Notes:

(1) Average of all data collected after FPC-1 treatment occurred in 6/93.

(2) Same as (1) except first 500 hours of operation after treatment excluded as this is normal carbon cleanup period.

(3) Too few data points for baseline so valid comparison could not be made.

III. CONCLUSION

The FMC Corporation Dry Valley Mine data generated to-date demonstrates a significant reduction in engine wear as evidenced by reductions in both iron (Fe) and copper (Cu) wear metal levels. Iron levels have been reduced up to 22.4% and copper levels have been reduced up to 40.5% (See attached data).

UNIT # 101 – FMC Dry Valley
Oil Analysis Data
Cat 3516 (P&H 2250)
Engine Hours: 7/30/92 – 203
11/7/94 – 203

	Sample Date	Hours On Oil	Soot % Allow	Soot % Hour	Iron Ppm	Iron Ppm/hr	Copper Ppm	Copper Ppm/hr	
	7/30/92	203	27	0.133	19	0.094	26	0.128	
	8/27/92	115	23	0.20	8	0.070	5	0.043	
	9/25/92	295	79	0.268	23	0.078	17	0.058	
	12/10/9	248	54	0.218	16	0.065	6	0.024	
	1/21/93	241	53	0.220	15	0.062	6	0.025	
	3/11/93	263	52	0.198	21	0.080	4	0.015	
	6/21/93	228	58	0.254	15	0.066	5	0.022	
Baseline Avg.				0.213	17	0.074	10	0.031	
	8/19/93	273			17	0.062	7	0.026	
	9/15/93	224			14	0.063	5	0.022	
	10/21/9	276	83	0.301	14	0.051	4	0.014	
	11/11/9	202	80	0.396	13	0.064	4	0.020	
	12/3/93	281	58	0.206	12	0.043	3	0.011	
	1/3/94	236	72	0.305	14	0.059	4	0.017	
	1/25/94	293	65	0.222	12	0.041	4	0.014	
	2/22/94	257	68	0.274	14	0.059	4	0.017	
	3/17/94	251	66	0.263	12	0.048	4	0.016	
	04/8/94	164	32	0.195	9	0.055	3	0.018	
	05/2/94	259	69	0.266	13	0.050	5	0.019	
	07/07/9	318	99	0.311	21	0.066	5	0.016	
	08/15/9	232	87	0.375	19	0.082	5	0.022	
	11/794	257	80	0.311	17	0.066	4	0.016	
FPC-1 Treated Avg				0.285		0.258		0.018	
Percent Change				33.8%		-21.6%		41.9%	

FPC-1 Treated Avg				0.285		0.058		0.018	
	Percent Change					-21.6%		-41.9%	
		* Percent Change				-23.0%		-45.2%	

* Change if first two samples after FPC-1 treatment are removed.

EVALUATION OF FPC-1® FUEL PERFORMANCE CATALYST
at

BFI HOLDING
Oosterbeek, Netherlands

Report Prepared by

UHI CORPORATION
PROVO, UTAH,
and
FPC LIMITED
HOUSTON, TEXAS

NOVEMBER 18, 1994

Report No. SOTR 112R

CONTENTS

INTRODUCTION

FPC-1® is a combustion catalyst which, when added to liquid hydrocarbon fuels at a ratio of 1:5000, improves the combustion reaction resulting in increased engine efficiency and reduced fuel consumption. The products of incomplete combustion are also positively affected.
Field and laboratory tests alike indicate a potential to reduce fuel consumption in diesel fleets in the range of 5% to 10%. Smoke and carbon monoxide emissions are typically reduced 15% to 30%. This report summarizes the results of controlled back-to-back field tests conducted by UHI Corporation, FPC Limited, and BFI Holding, with and without FPC-1® added to the diesel fuel. The fuel consumption determination procedure applied was the Carbon Balance Exhaust Emission Test at a given engine load and speed. This same method also measures the exhaust concentrations of carbon monoxide and unburned hydrocarbons. Smoke testing was also conducted using the Bacharach Smokemeter method.

EQUIPMENT TESTED

2 x DAF 75S 240 Trucks
1 x DAF 75 Truck
1 x DAF 2500 Truck
3 x DAF 2300 Trucks
1 x DAF 65 180 Truck
2 x DAF 85 330 Trucks
1 x Scania 81 Truck
1 x Scania 93H 280 Truck
1 x Mercedes 3528 Truck

TEST INSTRUMENTS:

The equipment and instruments involved in the carbon balance test program were:

Sun Electric SGA-9000 non-dispersive, infrared analyzer (NDIR) for measuring the exhaust gas constituents, HC (unburned hydrocarbons as hexane gas), CO, CO_2, and O_2.

Scott Specialty BAR 90 calibration gases for SGA-9000 internal calibration of the SGA-9000.

A Fluke Model 51 type "k" thermometer and wet/dry probe for measuring exhaust, fuel, and ambient temperature.

A Dwyer magnehelic and pitot tube for exhaust pressure differential measurement and exhaust air flow determination (CFM).

A Monarch phototachometer to determine and control engine speed (rpm).

A Bacharach True-Spot smokespot meter to determine the density of exhaust smoke from diesel engines.

A hydrometer for fuel specific gravity (density) measurement.

A Gateway 2000 Colorbook Notebook computer and Excel Pro program to calculate the engine performance factors.

A Snap On throttle control for setting and holding engine speed at a fixed rpm.

TEST PROCEDURE

Carbon Balance

The carbon balance technique for determining changes in fuel consumption has been recognized by the US Environmental Protection Agency (EPA) since 1973 and is central to the EPA-Federal Test Procedures (FTP) and Highway Fuel Economy Test (HFET). The method relies upon the measurement of vehicle exhaust emissions to determine fuel consumption rather than direct measurement (volumetric or gravimetric) of fuel consumption.

The application of the carbon balance test method utilized in this study involves the measurement of exhaust gases of a stationary vehicle under steady-state engine conditions. The method produces a value of engine fuel consumption with FPC-1® relative to a baseline value established with the same vehicle.

Engine speed and load are duplicated from test to test, and measurements of carbon containing exhaust gases (CO_2, CO, HC), oxygen (O_2), exhaust and ambient temperature, and exhaust and ambient pressure are made. A minimum of five readings are taken for each of the above parameters after engine stabilization has taken place (rpm, and exhaust, oil, and water temperatures have stabilized). The technical approach to the carbon balance method is detailed in the Appendices.

Fuel specific gravity or density is measured enabling corrections to be made to the final engine performance factors based upon the energy content of the fuel reaching the injectors.

Smoke density was determined by drawing a fixed quantity of exhaust gases through a filter medium. The particulate's were collected onto the filter surface and the density determined by comparing the discoloration of the filter paper to a color calibrated scale.

Thirteen trucks made up the FPC-1® treated test fleet. Table 1 in the Appendices summarizes the percent change in fuel consumption based upon the change in carbon flow rate in the exhaust.

DISCUSSION

The Effect of FPC-1® Upon Smoke Density and Carbon Monoxide Emissions

Smoke density was determined using the Bacharach smoke spot method. The Bacharach TrueSpot Smokemeter measures smoke density by drawing a specific volume of exhaust gas through a fine paper filter medium (5 micron) while the engine is operating at a fixed rpm and under steady-state engine conditions. The smoke particles are trapped on the surface of the filter paper as the exhaust gases are drawn through it forming a darkened area called a "smoke spot". The filter paper is then removed from the smoke tester and the smoke spot visually compared to a precoded smoke scale. A smoke number is then assigned to the smoke spot according to the darkness of the spot. The smoke number scale ranges from 0 to 9. Higher smoke numbers correspond to darker smoke spots, which correspond to a greater smoke density in the exhaust. The baseline and treated fuel smoke spot numbers are found on Table 2 in the Appendices.

Carbon monoxide (CO) levels were measure using the Sun Electric SGA-9000 non-dispersive infrared analyzer. Like the Bacharach Smokemeter, this too is a recognized method for determining carbon monoxide levels in the exhaust of an internal combustion engine. The SGA9000 measures CO as a percent of the total volume of gases in the exhaust stream. The baseline and treated fuel CO percentages are found on Table 2.

A reduction in smoke and CO is prime evidence of improved combustion (Germane, SAE Technical Paper # 831204). Further, reduced exhaust smoking has been shown to be one of first evidences that engine carbon residue and soot blowby into the motor oil are also being reduced (ibid). The reductions in exhaust smoke and CO are logical extensions of improved combustion created by FPC-1®.

CONCLUSIONS

1) The fuel consumption change determined by the carbon balance method ranged from +3.45 to -13.37%. **The fleet averaged a 7.40% reduction in fuel consumed after FPC-1® fuel treatment and engine preconditioning.** The average reduction on fuel consumption is virtually identical to that realized by dozens of fleets in the U.S. and Australia.

2) **Smoke density was reduced approximately 18% with FPC-1® treated fuel.**

3) Carbon Monoxide levels were reduced approximately 18.5% with treated fuel.

4) The reductions in smoke and carbon monoxide emissions support the fuel consumption reductions.

APPENDICES

CARBON BALANCE METHOD TECHNICAL APPROACH:

All test instruments were calibrated and zeroed prior to both baseline and treated fuel data collection. The SGA-9000 NDIR exhaust gas analyzer was internally calibrated using Scott Calibration Gases (BAR 90 Gases), and a leak test on the sampling hose and connections was performed. The same procedure was repeated after each test segment to determine any instrument drift.

Each vehicle's engine was brought up to operating temperature at a set rpm and allowed to stabilize as indicated by the engine water and exhaust temperature, and exhaust pressure. No exhaust gas measurements were made until each engine had stabilized at the rpm selected for the test. Engine rpm was set using the dash mounted tachometer and checked periodically to prevent any change in engine speed during the data collection period. #2 diesel was used exclusively throughout the evaluation. Fuel specific gravity (density) was also taken.

The baseline fuel consumption test consisted of a minimum of five sets of measurements of CO_2, CO, HC, O_2, and exhaust temperature and pressure made at 90 second intervals. Each engine was tested in the same manner. Engine rpm were also recorded at approximately 90 second intervals.

After the baseline test the fuel storage tanks were treated with FPC-1® at the recommended level of 1 oz. of catalyst to 40 gallons of fuel (1:5000 volume ratio). Each succeeding fuel shipment was also treated with FPC-1®. The equipment was operated on treated fuel until the final test was run.

During the two test segments, an internal self-calibration of the exhaust analyzer was performed after every two sets of measurements to correct instrument drift, if any.

From the exhaust gas concentrations of CO_2, CO, HC, and O_2 measured during the test, the average molecular weight of these gases, and the temperature and volumetric flow rate of the exhaust stream, the mass flow rate of the fuel to the engine (rate of fuel consumption) may be expressed as a engine "performance factor" which relates the fuel consumption of the treated fuel to the baseline. The calculations are based on the assumption that engine operating conditions are essentially the same throughout the test. Engines with known mechanical problems or having undergone repairs affecting fuel consumption are removed from the sample.

A sample calculation is found in Figure 2.

COMPUTER PRINTOUTS

Table 1:
Summary of Carbon Balance Fuel Consumption Changes

Unit	Engine	% Change Fuel Consumption
BBDL84	DAF	- 5.12
BBGJ76	DAF	- 6.15
BBDR35	DAF	- 13.37
VB65DY	DAF	+ 3.45 (1)
VF10BG	DAF	- 9.45
VN52RX	DAF	- 11.84
BN05XD	DAF	- 9.10
VX34DK	DAF	- 6.74
BBG103	DAF	- 8.81
VX15HX	DAF	- 6.94
86NB64	Scania	- 3.65
VJ72KH	Scania	- 10.19
VB43NS	Mercedes	- 8.79
	Average:	**- 7.40%**

(1) Statistical Anomaly, however included in the fleet average

Table 2:
Comparison of Smoke Spot Numbers

Unit No.	Base SS#	Treated SS#	
BBDL84	4.0	4.0	
VX15HX	5.0	4.5	
BBG103	5.0	4.0	
BN05XD	4.5	3 .5	
VX34DK	3.5	3.0	
BBGJ76	3 .5	4.0	
VJ72KH	3 .5	2.5	
VB43NS	6.5	5.0	
BBDN35	4.5	4.0	
VN52RK	5.0	4.0	
VF10BG	3.5	3.0	
VB65DY	4.0	3.5	
86NB64	5.5	3 .0	
Average:	**4.5**	**3.7**	**% Chg:- 17.8**

Table 3:
Summary of Carbon Monoxide (CO) Changes

Unit No.	Base CO	Treated CO	
BBDL84	.030	.023	
VX15HX	.026	.020	
BBG103	.030	.023	
BN05XD	.060	.060	
VX34DK	.030	.032	
BBGJ76	.030	.027	
VJ72KII	.030	.020	
VB43NS	.030	.023	
BBDN35	.040	.030	
VN52RX	.040	.032	
VF10BG	.050	.040	
VB65DY	.070	.053	
86NB64	.030	.021	
Average:	**.038**	**.031**	**%Chg: -18.4**

Figure 1
CARBON MASS BALANCE FORMULAE

ASSUMPTIONS: $C_{12}H_{26}$ and SG = 0.82
Time is constant
Load is constant

DATA:

Mwt	= Molecular Weight
pf1	= Calculated Performance Factor (Baseline)
pf2	= Calculated Performance Factor (Treated)
PF1	= Performance Factor (adjusted for Baseline exhaust mass)
PF2	= Performance Factor (adjusted for Treated exhaust mass)
CFM	= Volumetric Flow Rate of the Exhaust
SG	= Specific Gravity of the Fuel
VF	= Volume Fraction
d	= Exhaust stack diameter in inches
Pv	= Velocity pressure in inches of HZO
P_B	= Barometric pressure in inches of mercury
Te	= Exhaust temperature °F

VFHC	= "reading" = 1,000,000
VFCO	= "reading" = 100
$VFCO_2$	= "reading" = 100
VFO_2	= "reading" = 100

EQUATIONS:

Mwt = (VFHC)(86)+(VFCO)(28)+(VFCO)(44)+(VFO)(32)+[(1 VFHC-VFCO-VFCOZ-VFOZ)(28)]

pf1 or pf2 =
$$\frac{3099.6 \times Mwt}{86(VFHC) + 13.89(VFCO) + 13.89(VFCO_2)}$$

CFM =
$$\frac{(d/2)^2\pi}{144}\{1096.2 \frac{Pv}{1.325(PB/ET+460}$$

PF1 or PF2 =
$$\frac{pf \times (Te + 460)}{CFM}$$

FUEL ECONOMY:
PERCENT INCREASE (OR DECREASE)
$$\frac{PF2 - PF1}{PF1} \times 100$$

Figure 2.

SAMPLE CALCULATION FOR THE CARBON MASS BALANCE

BASELINE:

Equation 1 (Volume Fractions)

$VFHC = 13.20/1,000,000$
$= 0.0000132$

$VFCO = 0.017/100$
$= 0.00017$

$VFCO_2 = 1.937/100$
$= 0.01937$

$VFO_2 = 17.10/100$
$= 0.171$

Equation 2 (Molecular Weight)

Mwt1 -(0.0000132)(86)+(0.00017)(28)+(0.01937)(44)+(0.171)(32)
+ [(1-0.0000132-0.00017-0.01937-0.171)(28)]

Mwt1 =28.995

Equation 3 (Calculated Performance Factor)

$$pf1 = \frac{3099.6 \times 28.995}{86(0.0000132) + 13.89(0.00017) + 13.89(0.01937)}$$

pf1 = 329,809

Equation 4 (CFM Calculations)

$$CFM = \frac{(d/2)^2 \pi}{144} 1096.2 \frac{Pv}{1.325(PB/ET+460)}$$

d =Exhaust stack diameter in inches
Pv =Velocity pressure in inches of H_2O
P_B =Barometric pressure in inches of mercury
Te =Exhaust temperature °F

$$CFM = \frac{(10/2)^2 \pi}{144} 1096.2 \frac{.80}{1.325(30.00/313.100+460)}$$

CFM = 2358.37

Equation 5 (Corrected Performance Factor)

$$PF1 = \frac{329.809(313.1 \text{ deg F} + 460)}{2358.37 \text{ CFM}}$$

PF1 = 108,115

TREATED:

Equation 1 (Volume Fractions)

VFHC = 14.6/1,000,000
= 0.0000146

VFCO = .013/100
= 0.00013

$VFCO_2$ = 1.826/100
= 0.01826

VFO_2 = 17.17/100
= 0.1717

Equation 2 (Molecular Weight)

Mwt2 = (0.0000146)(86)+(0.00013)(28)+(0.01826)(44)+(0.1717)(32)
+ [(1-0.0000146-0.00013-0.01826-0.1717)(28)]

Mwt2 = 28.980

Equation 3 (Calculated Performance Factor)

$$pf2 = \frac{3099.6 \times 28.980}{86(0.0000146) + 13.89(0.00013) + 13.89(0.01826)}$$

pf2 = 349,927

Equation 4 (CFM Calculations)

$$CFM = \frac{(d/2)^2\pi}{144} \; 1096.2 \; \frac{Pv}{1.325(PB/ET+460)}$$

d =Exhaust stack diameter in inches
Pv =Velocity pressure in inches of H_20
P_B =Barometric pressure in inches of mercury
Te =Exhaust temperature °F

$$CFM = \frac{(10/2)^2\pi}{144} \; 1096.2 \; \frac{.775}{1.325(29.86/309.02+460)}$$

CFM = 2320.51

Equation 5 (Corrected Performance Factor)

$$PF2 = \frac{349.927(309.02 \text{ deg F} + 460)}{2320.51 \text{ CFM}}$$

= 115,966

Fuel Specific Gravity Correction Factor

Baseline Fuel Specific Gravity - Treated Fuel Specific Gravity/Baseline Fuel Specific Gravity + 1

.840-.837/.840+ 1=1.0036

PF2 = 115,966 x Specific Gravity Correction

PF2 = 115,966 x 1.0036

PF2 = 116,384

Equation 6 (Percent Change in Engine Performance Factor:)

$$\% \text{ Change PF} = \frac{\text{PF2 - PF 1}}{\text{PF1}} \text{ X } 100$$

% Change PF = [(116,384 - 108,115)/108,115](100)

= +7.65

Note: A positive change in PF equates to a reduction in fuel consumption.

Abstract

This paper discussed the results of a field test conducted by BEC/allwaste, Birmingham, Alabama, to determine the economic and environmental benefits from fuel treatment with a unique combustion catalyst called FPC-1. The study was planned in cooperation with and approved by Mr. Frank Montgomery, Equipment Coordinator. The test was conducted by Mr. Mike Cencula, Purchasing Coordinator for BEC/allwaste, Mr. Craig Flinders, VP Tech Services for UHI Corporation and Messrs. Mark Newman and David Doctor of FPC Limited. The study conducted on a fleet of Cat and Cummins powered trucks and front loaders concluded the following:

(1) All engines realized reductions in fuel consumption after FPC-1 fuel treatment. The fleet averaged a 11.63% reduction in fuel consumption.

(2) FPC-1 treated fuel combusted more completely than the standard diesel. Unburned hydrocarbons (measured as n-hexane) were reduced 22.2%.

(3) Smoke density was reduced 23.9% after FPC-1 fuel treatment.

These results verify <u>substantial fuel cost savings and environmental benefits</u> can be derived from FPC-1 use throughout the entire BEC/allwaste fleet operation. Along with the obvious fuel cost savings, maintenance cost reductions are inevitable with FPC fuel treatment. Smoke is simply soot, which is comprised of unburned fuel droplets. It is soot that builds up on critical engine components (injectors, valves, rings, seats, pistons, etc.) reducing engine efficiency and accelerating wear. The very fact that FPC reduces visible smoke attests to its ability to prevent hard carbon (hardened soot) upon these critical engine components.

Motor oil will also stay carbon (soot) free longer, and thus maintain designed visocity between oil changes. In this manner, abrasion wear of bearings, liners and rings is reduced.

The paper also discusses a unique, recognized test method for determining the benefits of FPC-1 in the field. The method is known as the carbon mass balance, which is central to the EPA standardized Federal Test Procedures and Highway Fuel Economy Test. The method uses exhaust gas analysis under steady-state engine operation to determine both fuel consumption and exhaust emissions.

Introduction

FPC-1 Fuel Performance Catalyst is a burn rate modifier or catalyst, proven to reduce fuel consumption and increase engine horsepower in several recognized, independent laboratory tests, and dozens of independent field trials. The catalyst also has a remarkable impact upon the products of incomplete combustion that are regulated by emissions reduction legislation (smoke and carbon monoxide).
The intent of the trial by BEC/allwaste was to determine the degree of fuel consumption, and emissions reduction resulting from the addition of the FPC-1 catalyst to the blended diesel fueling a select fleet of compression ignition engine powered buses. The test methodology for determining fuel consumption is the carbon mass balance (cmb). The cmb method measures the carbon containing products of the combustion process (CO_2, CO, HC) found in the exhaust, rather than directly measuring fuel flow into the engine. Also, while conducting the cmb procedure, a Bacharach Smoke Spot method is used to determine smoke density in the exhaust of the diesel powered equipment.

This report summarizes the results of baseline and FPC-1 treated fuel consumption and emissions data, and computes and compares the mass flow rates (engine performance factors or PFs) for the same.

II. Discussion of Carbon Mass Balance Method

The carbon mass balance eliminates virtually all of the variables associated with field testing for fuel consumption changes. The method requires no modifications to fuel lines or engines, and can be conducted in a short period of time at minimal expense.

Instead of measuring fuel flow into the engine (ie., the weight or volume of the fuel),measurements are made of the exhaust gases leaving the engine. More precisely, the carbon containing gases in the exhaust are measured. The method is based upon the Law of Conservation of Matter, which states that atoms can neither be created nor destroyed. Since the engines only source of carbon is the fuel it consumes, the carbon measured in the exhaust must come from the fuel. By measuring the carbon going out of the engine in the form of products of combustion, the amount of carbon entering the engine can be determined.

Carbon Balance Calculation

The carbon leaving the engine is mainly in the form of carbon dioxide (CO_2),carbon monoxide (CO), unburned hydrocarbons (HC), and particulate (smoke). By collecting this data while the engine is operating at a given load and speed, the fuel flow rate into the engine can be accurately determined. When engine load and speed, along with other factors influencing fuel consumption are reproduced and/or monitored to make appropriate corrections, the carbon balance can be used to confidently determine changes in fuel consumption that might result from the use of a fuel catalyst, such as FPC-1.

With the carbon balance, engine efficiency is expressed in terms of engine performance factors. To calculate any change in engine performance, separate measurements are made with the engine running on base fuel (untreated) and FPC-1 treated fuel. Any changes are stated as percentage changes from the baseline.

A copy of the carbon balance equations is found on Figure 1 (Appendix 5). A sample calculation for illustration purposes is also attached (see Figure 2, Appendix 5). Additionally, the carbon balance can be used to determine the effect of FPC-1 upon harmful emissions, such as carbon monoxide and smoke.

III. Instrumentation

Precision, state-of –the-art instrumentation is used to measure the concentrations of carbon containing gases in the exhaust stream and other factors related to fuel consumption and engine performance. The instruments and their purposes are listed below:

1) A Sun ElectricSGA-9000 non-dispersive infrared (NDIR) four gas analyzer-measures the volume percent of CO2, CO, and oxygen (O2) in the exhaust, and the parts per million (ppm) of HC.
2) EPA I/M Calibration Gases- known gases used internally to calibrate the NDIR analyzer.
3) A twenty (20) foot sampling train and stainless steel exhaust gas probe-inserted into the engine exhaust pipe and used to draw a sample of exhaust gases to the analyzer.
4) A Fluke Model 52 hand held digital thermometer and wet/dry thermocouple probe-measures exhaust, ambient, and fuel temperature.
5) A Dwyer Magnehelic 2000 Series Pressure Gauge and pitot tube- measures exhaust air velocity and/or pressure.
6) A Monarch Contact/Noncontact digital tachometer and magnetic tape- measures engine rpm when dash mounted tachometers are unavailable.
7) A hydrometer and flask- determines fuel specific gravity (density).
8) Barometric pressure is acquired from local airport or weather station.
9) A Bacharach Truespot Smokemeter- for smoke density determination.

Except for engine speed, fuel density, and ambient readings, all data are collected by simply inserting probes into the exhaust stream while the engine is running at a fixed rpm and load, and the vehicle is stationary. No modifications or device installations are made to fuel system, nor are normal equipment work cycles disrupted.

IV. Technical Approach

The following technical approach was observed during both test segments:

1) All instruments are calibrated according to accepted protocol.
2) A sample of fuel is drawn from the fuel specific gravity and temperature are recorded.
3) Each piece of equipment to be tested is parked, brakes locked, and run out-of-gear at a specific engine speed (RPM) until engine water, oil, and exhaust temperature, and exhaust pressure have stabilized. Engine speed is controlled using either a hand held phototach, or the tachometer in the cab, and either a Snap-On throttle lock, a high idle switch, or the programmable computer onboard the truck or bus.
4) Engine hours (or mileage) are taken from hour meters or odometers installed on the equipment.
5) After engine stabilization, the exhaust gas sampling probe is inserted into the exhaust stream. The Autocal button is depressed and after the LED readouts clear, test personnel take multiple readings of carbon dioxide, carbon monoxide, unburned hydrocarbons, and oxygen, along with engine speed, exhaust temperature and pressure. Smoke readings are taken on the diesel engines after exhaust gas testing.
6) Periodically, ambient air temperature, atmospheric pressure, and relative humidity are recorded. Temperature readings are taken at the test site. Other ambient readings are acquired from local weather information services.
7) All data are recorded until technicians are confident the information is consistent and reproducible.
8) After completing the baseline, the test fleet fuel was treated with FPC-1. All equipment operated as normal for approximately 400 to 500 hours, at which time the above procedure was reproduced without alteration, except FPC-1 fuel treatment in the test fleet.

IV. Discussion

The data collected during the tests are summarized on the attached computer printouts (Appendix 1). From these data the volume fraction (VF) of each gas is determined and the average molecular weight (Mwt) of the exhaust gases computed. Next, the engine performance factor (pf) based upon the carbon mass in the exhaust is computed. The pf is finally corrected for intake air temperature and pressure (barometric), and total exhaust mass yielding a corrected engine performance factor (PF).

The PFs for the diesel engines are tabulated on Table 1 of Appendix 3. The carbon monoxide percentages are tabulated on Table 2 of Appendix 3. The smoke spot (smoke density) numbers for the diesel engines are found on Table 3 of Appendix 3.

Fuel consumption was reduced by 11.6% in the BEC/allwaste study. This is a slightly larger change than observed in prior tests on similar equipment. The results are consistent from

engine to engine, therefore, the confidence level in the results is high. However, it is most likely that the reduction in fuel consumption will be similar to that observed by other fleets under actual operating conditions (8% to 9%).

V. Conclusions

(1) The addition of FPC-1 to the diesel fleet created an 11.63% reduction in fuel consumption.

(2) Unburned hydrocarbon emissions were reduced 22.2% on a fleet average basis.

(3) Smoke density was reduced 23.9% after FPC-1 fuel treatment.

APPENDIX 1

Company Name: BEC/Allwaste Location: Birmingham
Date: 7/10/96

Test Portion: Baseline Stack Diam. 5 Inches

Engine Type: Cummins 400 Mile/Hrs 435249

Equipment Type: ID# 1247 Baro 30.08

Fuel Sp. Gravity .850 Temp: 68

Time 8:35

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
2200	381	1.05	0.04	36	1.86	18.3	
2200	382	1.05	0.04	35	1.86	19	
2200	381	1.05	0.04	36	1.86	19	
2200	382	1.05	0.04	35	1.83	18.9	
2200	382	1.05	0.04	35	1.83	18.9	
2200	383	1.05	0.04	36	1.86	19	
2200	383	1.05	0.04	37	1.84	19	
2200.00	**382.000**	**1.050**	**.040**	**35.714**	**1.849**	**18.871**	Mean
0	**.816**	**.000**	**.000**	**.756**	**.015**	**.256**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
3.57E05	0.0004	.018	.189	29.053	339,177	405,879

Company Name: BEC Allwaste Location: Birmingham Date: 09/12/96

Test Portion: Treated stack Diam: 5 Inches

Engine Type: Cummins 400 Mile/Hrs: 444766

Equipment Type: Kenworth ID# 1247 Baro: 29.92

Fuel Sp. Gravity: .850 Temp: 64
SG Corr Factor: 1.000 Time: 7:40

RPM	Exh Temp	Pv Inch	CO	HC	CO2	O2	
2200	374.4	1.05	0.04	28	1.63	19.2	
2200	374	1.05	0.03	30	1.62	19.2	
2200	372.8	1.05	0.04	30	1.62	19.3	
2200	373.2	1.05	0.03	31	1.63	19.3	
2200	372	1.1	0.03	32	1.63	19.3	
2200	371.4	1.1	0.03	32	1.61	19.4	
2200.000	**372.967**	**1.067**	**.033**	**30.500**	**1.623**	**19.283**	Mean
0	**1.148**	**.026**	**.005**	**1.517**	**.008**	**.075**	Std Dev

VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw2**	**pf2**	**PF2**
3.05E-05	.000333333	.016	.193	29.033	386,513	455,214

Performance factor adjusted for fuel density: 455,214 **** Change PF= 12.16 %**

**** A positive change in PF equates to a reduction in fuel consumption**.

Company Name: BEC Allwaste Location: Birmingham Date 07/10/96

Test Portion: Baseline Stack Diam. 5 Inches

Engine Type: Cat 3406 Mile/Hrs 112701

Equipment Type: Lo Boy ID# 4368 Baro 30.08

Fuel Sp. Gravity(SG .845 Temp: 70

Time: 9:00

RPM	ExhTemp	PvInch	CO	HC	CO2	O2	
1800	309	0.5	0.01	8	1.68	19.1	
1800	310.4	0.5	0.01	7	1.65	19.1	
1800	311.4	0.5	0.01	9	1.65	19.1	
1800	311.2	0.5	0.01	10	1.64	19	
1800	312	0.55	0.01	10	1.64	19.3	
1800	312	0.55	0.01	10	1.67	19.3	
1800	313	0.55	0.01	10	1.65	19.3	
1800	313.4	0.55	0.01	10	1.66	19.2	
1800.00	**311.550**	**.525**	**.010**	**9.250**	**1.655**	**19.175**	Mean
0	**1.409**	**.027**	**.000**	**1.165**	**.014**	**.116**	Std Dev

VFCH	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
9.25E06	0.0001	.017	.192	29.032	387,729	628,117

Company Name: BEC Allwaste Location: Birmingham
Date: 09/12/96

Test Portion: Treated Stack Diam. 5 Inches

Engine Type: Cat 3406 Mile/Hrs 121613

Equipment Type: Lo Boy ID# 4368 Baro: 29.92

Fuel Sp. Gravity: .844 Temp: 64
SG Corr Factor: 1.001 Time: 8:00

RPM	ExhTemp	PvInch	CO	HC	CO2	O2	
1800	308.4	0.5	0.01	6	1.52	19.2	
1800	309.4	0.5	0.01	6	1.5	19	
1800	310.5	0.5	0.01	6	1.51	19.5	
1800	310.8	0.5	0.01	6	1.51	19.6	
1800	311.4	0.55	0.01	9	1.5	19.5	
1800	312.2	0.55	0.01	7	1.49	19.5	
1800	312.6	0.55	0.01	6	1.48	19.6	
1800.000	**310.757**	**.521**	**.010**	**6.571**	**1.501**	**19.414**	Mean
0	**1.492**	**.027**	**.000**	**1.134**	**.013**	**.227**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
6.57E-06	0.0001	.015	.194	29.017	427,231	692,271

Performance factor adjusted for fuel density: 693,090 ****% Change PF = 10.34%**

**** A positive change in PF equates to a reduction in fuel consumption.**

Company Name: BEC Allwaste Location: Birmingham
Date: 07/10/96

Test Portion: Baseline Stack Diam. 4 Inches

Engine Type: Cat 3114 Mile/Hrs 5384

Equipment Type: Front End Loader ID# Baro: 30.08

Fuel Sp. Gravity(SG .842 Temp: 70

Time: 9:30

RPM	ExhTemp	PvInch	CO	HC	CO2	O2	
2538	439	0.7	0.01	6	2.45	18.5	
2538	445.8	0.7	0.01	7	2.46	18.4	
2538	455	0.7	0.01	8	2.44	18.5	
2538	455	0.7	0.01	6	2.45	18.5	
2538	457.8	0.7	0.01	8	2.42	18.5	
2538	458	0.7	0.01	8	2.41	18.5	
2538	457	0.7	0.01	6	2.4	18.5	
2538.00	**452.514**	**.700**	**.010**	**7.000**	**2.433**	**18.486**	Mean
0	**7.283**	**.000**	**.000**	**1.000**	**.023**	**.038**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
7.00E-06	0.0001	.024	.185	29.129	265,605	633,193

Company Name: BEC Allwaste Location: Birmingham
Date: 09/12/96

Test Portion: Treated Stack Diam: 4 Inches

Engine Type: Cat 3114 Mile/Hrs:

Equipment Type: Front End Loader ID# Baro:
29.92

Fuel Sp. Gravity: .847 Temp: 62
SG Corr Factor: .994 Time
9:00

RPM	ExhTemp	PvInch	CO	HC	CO2	O2	
Full	416.4	0.7	0.01	4	2.18	18.7	
Full	416.4	0.7	0.01	4	2.18	18.7	
Full	414.4	0.75	0.01	4	2.17	18.9	
Full	414.4	0.75	0.01	4	2.15	18.9	
Full	413.2	0.75	0.01	4	2.16	18.9	
Full	413.2	0.75	0.01	4	2.15	18.8	
Full	412.8	0.75	0.01	4	2.15	18.9	
Full	412.8	0.75	0.01	4	2.15	18.8	
#DIV/0!	**412.200**	**.738**	**.010**	**4.000**	**2.161**	**18.825**	Mean
#DIV/0!	**1.497**	**.023**	**.000**	**.000**	**.014**	**.089**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
4.00E-06	0.0001	.022	.188	29.099	298,717	677,261

Performance factor adjusted for fuel density: 673,239

**** % Change PF = 6.32 %**

**A positive change in PF equates to a reduction in fuel consumption.

Company Name: BEC Allwaste Location Birmingham Date: 07/10/96

Test Portion: Baseline Stace Diam.: 4 Inches

Engine Type: Cummins 5.9 Mile/Hrs.: 131507

Equipment Type: Ford Lube Truck ID# 1442 Baro: 30.07

Fuel Sp. Gravity (SG .845 Temp: 70

Time: 9:50

RPM	ExhTemp	PvInch	CO	HC	CO2	O2	
2500	381.4	1.25	0.03	9	1.79	18.9	
2500	377	1.25	0.03	10	1.8	18.9	
2500	378	1.25	0.03	10	1.78	18.8	
2500	379	1.25	0.03	9	1.78	19	
2500.000	**378.850**	**1.250**	**.030**	**9.500**	**1.788**	**18.900**	**Mean**
0	**1.886**	**.000**	**.000**	**.577**	**.010**	**.082**	**Std Dev**

VFHC VFCO VFCO2 VFO2 Mtw2 pf2 PF2

9.50E-06	0.0003	.018	.189	29.043	355,395	607,794

Company Name: BEC Allwaste Location: Birmingham Date: 09/12/96

Test Portion: Treated Stack Diam.: 4 Inches

Engine Type: Cummins 5.9 Mile/Hrs.: 139784

Equipment Type: Ford Lube Truck ID# 1442 Baro: 29.92

Fuel Sp. Gravity: .845 Temp: 62
SG Corr Factor: 1.000 Time: 9:30

RPM	ExhTemp	PvInch	CO	HC	CO2	O2	
2500	374.4	1.25	0.03	6	1.53	19	
2500	385.4	1.25	0.03	6	1.53	18.9	
2500	371	1.25	0.03	6	1.53	19.3	
2500	375.4	1.35	0.03	7	1.52	19.2	
2500	379.6	1.35	0.03	8	1.52	19.2	
2500.000	**377.160**	**1.290**	**.030**	**6.600**	**1.526**	**19.120**	Mean
0	**5.534**	**.055**	**.000**	**.894**	**.005**	**.164**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
6.60E-06	0.0003	.015	.191	29.009	414,909	696,040

Performance factor adjusted for fuel density: 696,040 **% Change PF= 14.52%**

** **A positive change in PF equates to a reduction in fuel consumption.**

Company Name: BEC Allwaste Location: Birmingham Date: 07/10/96

Test Portion: Baseline Stack Diam.: 5 Inches

Engine Type: Cat 3406-B Mile/Hrs.: 393677

Equipment Type: Lo Boy ID# 9354 Baro: 30.07

Fuel Sp. Gravity(SG .844 Temp: 72

Time: 10:00

RPM	ExhTemp	PvInch	CO	HC	CO2	O2	
1855	309	0.35	0.02	8	1.31	19.4	
1855	312.8	0.35	0.02	8	1.29	19.4	
1855	319	0.35	0.02	7	1.29	19.4	
1855	319	0.35	0.02	7	1.31	19.4	
1855	320	0.35	0.02	8	1.33	19.4	
1855	320	0.35	0.02	8	1.32	19.4	
1855.000	**316.633**	**.350**	**.020**	**7.667**	**1.308**	**19.400**	Mean
0	**4.622**	**.000**	**.000**	**.516**	**.016**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw1	pf1	PF1
7.67E-06	0.0002	.013	.194	28.986	485,152	965,584

Company Name: BEC Allwaste Location: Birmingham Date: 09/12/96

Test Portion: Treated Stack Diam.: 5 Inches

Engine Type: Cat 3406-B Mile/Hrs: 402736

Equipment Type: Lo Boy ID# 9354 Baro: 29.92

Fuel Sp. Gravity: .850 Temp: 62
SG Corr Factor: .993 Time: 10:20

RPM	ExhTemp	PvInch	CO	HC	CO2	O2	
1865	304.4	0.35	0.02	7	1.1	19.7	
1865	307.4	0.35	0.02	7	1.09	19.6	
1865	310.8	0.35	0.02	6	1.09	19.7	
1865	311.8	0.35	0.02	6	1.09	19.7	
1850	316.8	0.4	0.02	6	1.07	19.8	
1850	314	0.4	0.02	6	1.07	19.8	
1850	313.4	0.4	0.02	5	1.08	19.8	
1850	313.2	0.4	0.02	5	1.07	19.8	
1857.500	**311.475**	**.375**	**.020**	**6.000**	**1.083**	**19.738**	Mean
8.017837257	**3.939**	**.027**	**.000**	**.756**	**.012**	**.074**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2
6.00E-06	0.0002	.011	.197	28.963	584,194	1,116,746

Performance factor adjusted for fuel density: 1,108,807 ****%Change PF = 14.83%**

****A positive change in PF equates to a reduction in fuel consumption.**

APPENDIX 3

Table 1. Changes in Fuel Flow Rate (PFs)

Unit#	Base PF	FPC PF	% Change
4368	628,117	693,090	10.34
Loader	633,193	673.239	6.32
1247	405,879	455,214	12.16
Lube Truck	607,794	696,040	14.52
9354	965,584	1,108,807	14.83
		Fleet Average:	11.63

Note: An increase in PF equals a reduction in fuel consumption since the PF is a measure of the length of time required to consume the same amount of fuel.. The more efficient the engine, the longer it takes to consume the same amount of fuel, so the PF is higher.

Table 2. Changes in Somke Density (Smoke Spot Numbers)

Unit#	Base No.	FPC No.	% Change
4368	na	4.0	na
Loader	4.0	3.0	-25.0
1247	5.5	3.5	-36.4
Lube Truck	5.0	4.0	-20.0
9354	7.0	6.0	-14.3

Fleet Average: -23.9

APPENDIX 4

Fuel Specific Gravity Correction Factor

Baseline Fuel Specific Gravity – Treated Fuel specific Gravity/Baseline Fuel Specific Gravity + 1

.840-.837/.840+1 = 1.0036

PF2 = 115,966 x Specific Gravity Correction

PF2 = 115,966 x 1.0036

PF2 = 116,384

Equation 6 (Percent Change in Engine Performance Factor:)

% Change PF = $\mathbf{\frac{PF2-PF1}{PF1} \times 100}$

% Change PF = (116,384 – 108,115)/108,115)(100)

= + 7.65

Note: A positive change in PF equates to a reduction in fuel consumption.

APPENDIX 2

APPENDIX 5

WEATHERBANK, INC.

HIGH TECHNOLOGY SOLUTIONS TO CURRENT ENVIRONMENTAL CHALLENGES

Time	Pressure	Temp
12am	29.97	72
1am	29.98	72
2am	29.99	72
3am	29.99	71
4am	29.99	71
5am	30.01	69
6am	30.03	68
7am	30.05	65
8am	30.08	68
9am		No Report
10am		No Report
11am		No Report
12pm		No Report
1pm		No Report
2pm		No Report
3pm		No Report
4pm	30.06	85

WBI1 More info on how to call up WeatherBank files
WIND How to get specific upper level wind forecasts
WWC How to obtain the NWS Weekly Crop outlook

ZONES How to obtain the new NWS state zone forecasts Interactively
800NET More information on the 800 network and prices
7DTF How to call up 7-day temperature forecasts

EXAMPLE:

HELP HOURLY Will call up help on the HOURLY command.

NOTES:
To download information about the WeatherBrief software and how to obtain the service, type HELP INFO.
To control data flow, hit a <CONTROL> S to pause, and <CONTROL> Q to go.
To kill current command in a command file, hit a <CONTRO> X.
To abort transmission of any product, hit a single CONROL C.
To recall last command, hit a <CONTROL> R.

STATION FILE: AL 09-12-08 GMT

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND GST	PRSSR	VSBLY-WX	CLOUD COVER
12-08A*	Muscle Shoal								
12-09A*	Muscle Shoal								
12-10A*	Muscle Shoal								
12-11A*	Muscle Shoal	62	60	93	62	W 4	29.97	3 BR	SKC
12-12P	Muscle Shoal	60	60	100	60	W 4	29.98	3 BR	SKC
12-01P	Muscle Shoal	66	64	93	66	NW 4	29.98	3 BR	SKC
12-02P	Muscle Shoal	71	64	79	69	NW 5	29.98	5 HZ	SKC

DY-HR TOWN TMP DEW HUM FLK WIND GST PRSSR VSBLY-WX CLOUD COVER

12-08A	Huntsville	62	62	100	62	N	0	29.93	5	BR	CLR
12-09A	Huntsville	60	60	100	58	NW	5	29.95	4	BR	CLR
12-10A	Huntsville	60	60	100	60	NW	4	29.96	7		CLR
12-11A	Huntsville	60	60	100	60	N	0	29.96	7		CLR
12-12P	Huntsville	60	60	100	60	N	0	29.98	7		CLR
12-01P	Huntsville	64	62	93	64	N	0	29.98	7		CLR
12-02P	Huntsville	69	62	79	69	N	0	29.98	6	HZ	CLR

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX		CLOUD COVER
12-08A	Tuscaloosa	66	64	93	66	N	0	29.91	5	BR	SKC
12-09A	Tuscaloosa	64	64	100	64	N	0	29.91	4	BR	SKC
12-10A	Tuscaloosa	64	64	100	64	N	0	29.90	5	VCFG	SKC
12-11A	Tuscaloosa	64	62	93	64	N	0	29.90	5	BR	SKC
12-12P	Tuscaloosa	64	62	93	62	N	5	29.95	5	BR	SKC
12-01P	Tuscaloosa	68	64	87	66	N	5	29.96	6	BR	SKC
12-02P	Tuscaloosa	73	66	79	76	N	5		7		SKC

DY-HR	TOWN	TMP	DEW	HUM	FLK	WIND	GST	PRSSR	VSBLY-WX		CLOUD COVER
12-08A	Birmingham	64	62	93	64	N	0	29.92	8		SKC
12-09A	Birmingham	62	60	93	62	N	0	29.92	7		SKC
12-10A	Birmingham	62	60	93	62	N	0	29.92	7		SKC
12-11A	Birmingham	62	62	100	62	N	0	29.94	5	BR	SKC
12-12P	Birmingham	62	60	93	62	NE	3	29.95	4	BR	SKC
12-01P	Birmingham	66	64	93	66	N	0	29.96	4	BRHZ	SKC
12-02P	Birmingham	69	64	84	69	N	4	29.96	5	HZ	SKC

WESFARMERS COAL

Evaluation of FTC Combustion Catalyst as a means of reducing diesel fuel costs in mobile mining equipment

August, 2001

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CONTENTS

Appendix

EXECUTIVE SUMMARY

The FTC/FPC Combustion Catalysts manufactured and marketed by Fuel Technology Pty Ltd have proven in laboratory and field trials to significantly reduce fuel consumption under comparable load conditions and to also substantially reduce carbon emissions.

Following meetings with Wesfarmers Coal Maintenance Manager, Bob Garrick, Mobile Equipment Superintendent, Barry Giblett and Workshop Supervisor, Rod Simmonds, it was agreed that a fuel efficiency study should be conducted on a Komatsu 830E and a Euclid R260 employing "Specific Fuel Consumption procedure". This trial commenced on 11th April 2001 and was due to be completed 6-8 weeks later. Due to changing haul profiles the second stage of this trial was unable to be completed and following further discussions with Wesfarmers Coal management it was agreed to conduct static tests employing the "Carbon Mass Balance" (CMB) procedure.

The net average efficiency gain (reduction in fuel consumption) measured by the CMB test methods was **7.3%**.

BACKGROUND

The FTC Combustion Catalyst is the only fuel chemical yet proven by the world's leading testing authority, Southwest Research Institute (Texas) to improve fuel efficiency in an as new 2500HP diesel engine operating at its most efficient state. SwRI also determined that FTC does not alter the physical or chemical properties of diesel fuel.

SwRI also determined, using the Caterpillar 1G2 Test (ASTM 509A) that there are no detrimental effects that could cause increased wear or deposit problems following catalyst treatment of fuel.

These findings have been verified by countless field studies in diverse applications, which have confirmed efficiency benefits for mine mobile equipment. Maintenance benefits documented include reduced wear metal profiles in lubricating oil and reduced soot. Combustion and exhaust spaces become essentially free of any hard carbon with continuous catalyst use.

FTC's action in producing fuel efficiency gains is to promote a faster fuel burn which releases the fuel's energy more efficiently. That is, a larger portion of the fuel burn occurs when the piston is closer to top dead centre.

INTRODUCTION

Equipment provided for this fuel efficiency evaluation comprised of three Euclid Detroit 4000 series powered haul trucks and two Komatsu Detroit 149 powered trucks.

Fuel Technology Pty Ltd supplied, on loan, an air operated FTC catalyst metering system which was calibrated allowing fuel to be FTC treated at time of fuel service trucks being filled.

Due to change in test circuit profile and subsequently the change in test methods plus the fact that fuel was being FTC treated prior to commencement of CMB static tests, these tests were conducted in reverse, that is FTC treated tests were conducted on the 3rd July 2001 at which time treatment of fuel ceased and return to untreated fuel tests conducted on 31st July 2001.

TEST METHOD

<u>The Carbon Mass Balance (CMB)</u> is a procedure whereby the mass of carbon in the exhaust is calculated as a measure of the fuel being burned. The elements measured in this test include the exhaust gas composition, (HC,CO,CO_2 and O_2) temperature and the gas flow rate calculated from the differential pressure and exhaust stack cross sectional area. This is an engineering standard test (AS2077-1982) and has been used by the US EPA since 1974 as the "Standard Federal Test Procedure" for fuel economy and emission testing.

Each test truck was driven to the workshop where CMB test probe was positioned in the exhausts independently. With the assistance of workshop personal the test truck engine was loaded via electrical load box to simulate operating conditions. The rpm and hp were recorded to allow these operating parameters to be repeated during the second stage of the test.

TEST RESULTS

A summary of the CMB fuel efficiency results achieved in this test program are provided in the following table.

TABLE 1
Carbon Balance Fuel Consumption Test Results

Unit No.	Untreated 31/7/01 Carbon flow g/s	Treated 3/7/01 Carbon flow g/s	Variation
1131 Front Exhaust	48.044	45.217	
1131 Rear Exhaust	51.750	49.170	
TOTAL g/s	**99.175**	**94.387**	**-4.8%**
1132 Front Exhaust	43.692	41.245	
1132 Rear Exhaust	33.778	31.596	
TOTAL g/s	**77.470**	**72.841**	**-6.0%**
1137 Right Exhaust	49.361	46.721	
1137 Left Exhaust	47.511	43.241	
TOTAL g/s	**96.872**	**89.962**	**-7.1%**
1139 Right Exhaust	51.814	20.665	
1139 Left Exhaust	49.387	22.194	
TOTAL g/s	**101.201**	**42.859**	**-57.6%**
1140 Right Exhaust	44.678	39.858	
1140 Left Exhaust	49.564	43.813	
TOTAL g/s	**94.242**	**83.671**	**-11.2%**
AVERAGE EXCLUDING # 1139	**367.759**	**340.861**	**- 7.3%**

The CMB test procedure provides confirmation that addition of the Catalyst to the fuel supply has resulted in a reduction in carbon flow (fuel consumption) of **7.3%** excluding truck 1139. Tests conducted on truck 1139 indicate that during CMB treated test the truck may not have been producing the hp as measured. The computer printouts of results and raw data sheets are contained in the *Appendix*.

Following are photographs showing CMB measurements and Bosch smoke sampling in process.

BOSCH SMOKE MEASUREMENTS

A Bosch smoke test is also undertaken during conduct of the CMB test and the results are shown in the following table. Significant reductions in smoke particulates are not generally measured after only one month's running on FTC/FPC treated fuel or in this case only 3 weeks return to untreated fuel. Smoke patches in *Appendix*.

TABLE 2
Bosch Smoke Results

Unit No.	Untreated 31/7/01	Treated 3/7/01	Variation
1131 Front	0.6	0.4	
1131 Rear	0.6	0.3	
AVERAGE	**0.6**	**0.35**	**- 41%**
1132 Front	0.2	0.4	
1132 Rear	0.2	0.1	
AVERAGE	**0.2**	**0.25**	**+ 25 %**
1137 Right	0.5	0.6	
1137 Left	0.5	0.4	
AVERAGE	**0.5**	**0.5**	**N/C**
1139 Right	2.2	0.6	
1139 Left	0.7	0.7	
AVERAGE	**1.45**	**0.65**	**- 55 %**
1140 Right	0.6	0.6	
1140 Left	0.5	0.5	
AVERAGE	**0.55**	**0.55**	**N/C**
Average Excluding # 1139	**1.85**	**1.65**	**-10.8 %**

GREENHOUSE GAS REDUCTION

A gross reduction of **7.3%** of the current estimated annual fuel consumption of 18,000 KL translates to a **3,799 tonnes per annum** reduction in CO_2 emissions, based on the formula outlined in Worksheet 1 of the "Electricity Supply Business Greenhouse Change Workbook". Our estimate is based on the following calculations:-

(18,000 KL x 38.6 x 74.9) ÷ 1000 = 52,041 tonnes CO_2 per annum

- 7.3% (16,686 KL x 38.6 x 74.9) ÷ 1000 = 48,242 tonnes CO_2 per annum

CO_2 reduction by application FPC Catalyst
52,041 – 48,242 = 3,799 tonnes

CONCLUSION

These carefully controlled engineering standard test procedures conducted on a selection of Wesfarmers Coal fleet provide clear evidence of average reduced fuel consumption of **7.3%**.

A fuel efficiency gain of **7.3%** as measured by the Australian Standards (AS2077) CMB test method, if applied to the total fuel currently consumed by Wesfarmers Coal will result in a **net** saving of in excess of **$550,000 per annum.**

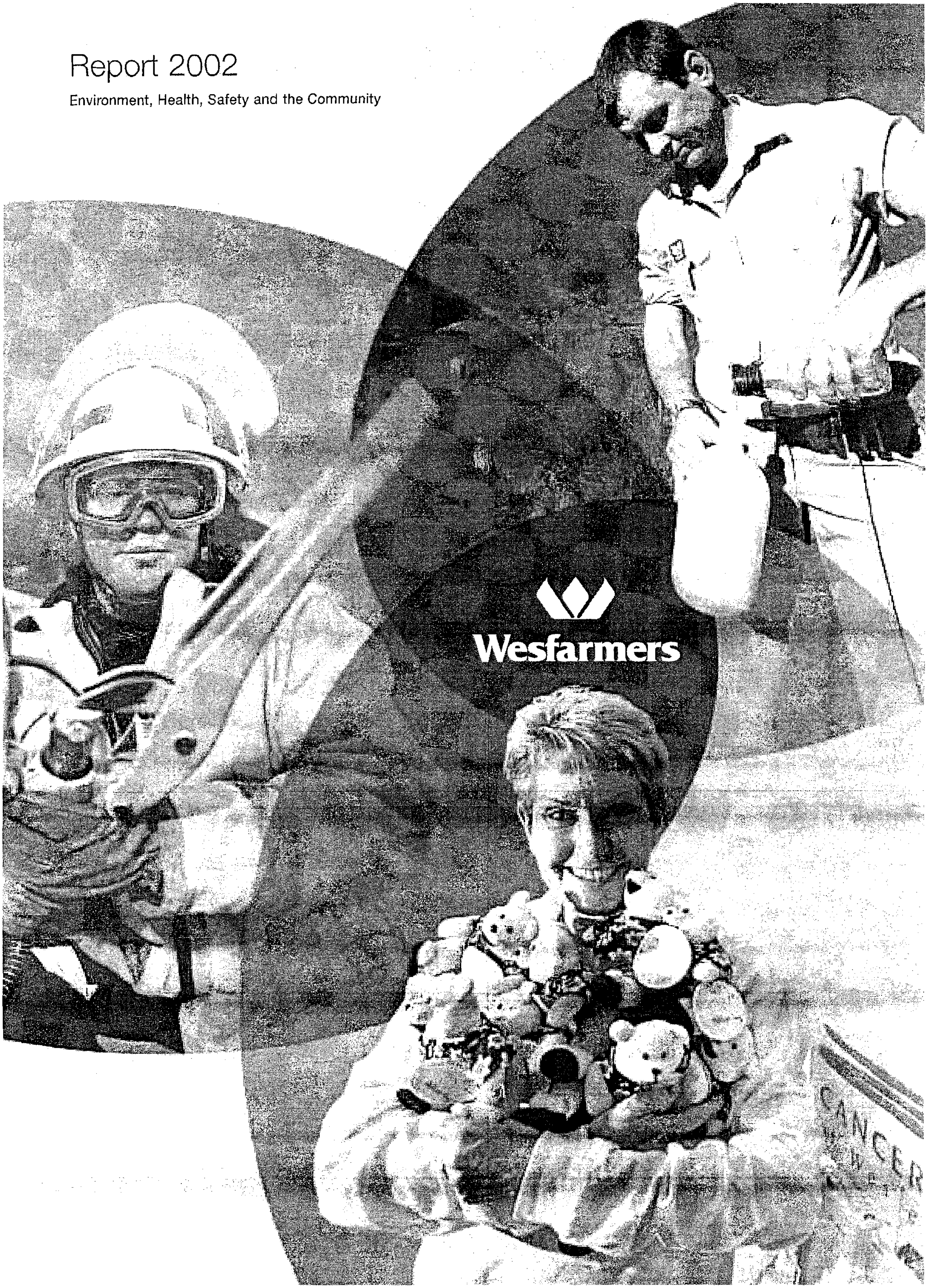
Additional to the fuel economy benefits measured, is a reduction in greenhouse gas emissions of 3,799 tonnes per annum due to more complete combustion of the fuel. Further, the more complete combustion will translate to significant reduction over time in engine maintenance costs. FTC/FPC also acts as an effective biocide.

Appendix "D"

Fuel Technology Measurements using Carbon Balance Techniques

Report 2002

Environment, Health, Safety and the Community



Greenhouse emissions

We are a participant in the Commonwealth Greenhouse Challenge Programme and have a signed Cooperative Agreement.

Our greenhouse emissions are largely due to use of diesel fuel and electricity with a smaller contribution from spontaneous combustion of coal. Collie coal has no associated methane emissions. The sources of emissions can be seen in Figure 2.

Net carbon dioxide (CO_2) emissions per bank cubic metre equivalent (bcmeq) were down 52 per cent from 1994 levels, an increase of two per cent on 2001. Net emissions were 72,628 tonnes of CO_2 down eight per cent on last year due to lower production levels. In the last year, emissions increased from 2.45kg/bcmeq to 2.57kg/bcmeq (4.9 per cent) due to efficiency losses associated with the lower production level.

During the year we completed one Greenhouse Challenge commitment to install a lighting control system in the workshop and warehouse areas. This is expected to reduce CO_2 emissions by nearly 1,000 tonnes a year.

As well, we introduced a diesel fuel additive system. Since November 2001, fuel consumption has dropped nine per cent, equating to 1,730 tonnes of CO_2.

A comprehensive in-house study was completed into greenhouse, climate change, global warming and the role of energy supplies with a particular emphasis on renewables, new high efficiency generation systems and low to zero emission technologies.

Noise

Our equipment noise levels have not increased, even though the operations have moved closer to our neighbours at Buckingham. Consultation continues with the DEP and the community.

Blasting improvement strategies, although offset by moving closer to residents, are delivering results and we have been able to maintain our low blasting level average [101dB(L)], with no blasts exceeding the legal limit of 125dB(L) (see Figures 3 and 4.)

The highest recorded blast was 119dB(L) while 98.3 per cent were below 115dB(L). While there was a 25 per cent increase in the total number of blasts, we managed to improve the number not triggering the monitor, set at 115dB(L), by 12 per cent, a very positive trend.

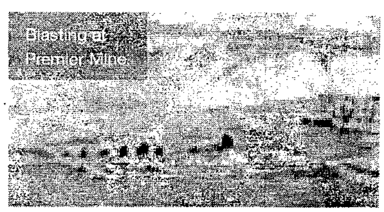
There were nine complaints for blasting on our site for blast levels ranging from 94 dB(L) to 118dB(L) of which six were below 115dB(L).

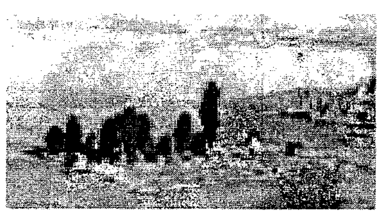
Independent building condition surveys are on offer to all nearby neighbours but to date no survey has attributed structural defects to our blasting.

Water

Abstraction

Dewatering is required for safe and efficient mining in the Collie Basin. All groundwater abstraction, a part of the dewatering process, is licensed and monitored. During the year, 12.5ML/day were pumped with a total abstraction of 4,547ML (see Figure 5).

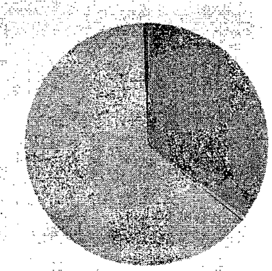




Blasting at Premier Mine.

Figure 2: CO_2 Emissions by Source

Electricity	35.1%
LPG	0.5%
Petrol	0.2%
Diesel	
Spontaneous Combustion	3.5%
Explosives	0.6%



Year ended 30 June 2002

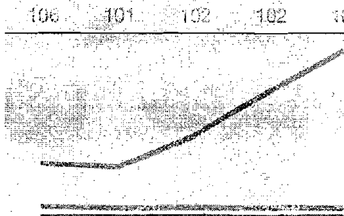
Figure 3. Premier Mine Blasting 2001/2002

Criteria	Buckingham	Griggs
<125dB(L)	100%	100%
<120dB(L)	100%	100%
<115dB(L)	98.3%	100%
Average dB(L) when triggered	101	108
Total Blasts	596	596
Not triggered	443	558

Year ended 30 June 2002

Figure 4. Premier Mine Blasting Buckingham Monitor

	1998	1999	2000	2001	2002
Total blasts	271	261	349	477	596
Number below 115dBL	261 96%	254 97%	343 98%	455 95%	586 98%
dBL average when triggered	106	101	102	102	101



Year ended 30 June 2002

TARONG FUEL COST REDUCTIONS

12 Months FTC-3 Combustion Catalyst Use

November 2003

Prepared by:

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C O N T E N T S

***E**xecutive **S**ummary*

Tarong Coal have been using the FTC-3 Combustion Catalyst throughout their mobile mining equipment for 12 months. This study compares the operating efficiency of the Truck and Shovel fleet for the treated period (Nov '02 to Oct '03) with the previous untreated 12 months period (Nov '01 to Oct '02).

With the increased mine production the amount of material shifted by the truck and shovel type operation increased by **59%**, machine operating hours increased by **51%**, but fuel consumed increased by only **40%** during the treated period.

The most meaningful measure of fuel efficiency is Tonnes shifted per litre of fuel consumed. Analysis of the mine records reveal a strong efficiency gain of **8.3%**. This represents a saving of in excess of 1.3 million litres of diesel in the last 12 months. This equates to an operating cost reduction of approximately **$550,000**.

In terms of environmental responsibility, Tarong have reduced their Greenhouse Gas emissions by 3584 Tonnes of CO_2.

Background

The manufacturer of the FTC Combustion Catalyst claim that it is the only fuel chemical yet proven by the world's leading testing authority, Southwest Research Institute (San Antonio, Texas) to improve fuel efficiency in an "*as new*" 2500 HP diesel engine operating at its most efficient state.

FTC's action in producing fuel efficiency gains is to cause a faster fuel burn which releases the fuel's energy more efficiently. That is, a larger percentage of the fuel burns when the piston is closer to top dead centre releasing its energy with greater mechanical advantage. FTC has a secondary action, to decarbonise combustion and exhaust spaces. This action can also produce efficiency gains where significant carbon build-up causes loss of efficiency.

A tightly controlled specific fuel consumption procedure on two Tarong Coal Dresser 630E trucks measured an average 6.2% fuel efficiency benefit when using this chemical. Based on this result a commitment was made to full fleet use commencing November 2002. An analysis of Tarong's operations after 6 months FTC-3 operation indicated a fuel efficiency improvement of 9.1%.

The following study compares Tarong's operations after 12 months FTC use with the previous untreated 12 months period. The study was undertaken by Mr Werner Ewald (of Tarong Coal) and Mr Brid Walker (of Cost Effective Maintenance). During this 24month period Tarong have introduced 3 additional Dresser 630E trucks and a third Hitachi excavator to achieve increased production targets.

***P**rocedure*

The study aims to quantify the fuel efficiency benefit provided by the FTC-3 Combustion Catalyst over the longer term (ie the twelve month period from Nov ’02 to Oct ’03). The untreated period (Nov ’01 to Oct ’02) was used as the reference point.

The following data for Tarong’s fleet was provided on a monthly basis.

Tonnes shifted (by Truck and Shovel operation)
Total litres diesel consumed by minesite
Equipment hours (Total of Trucks, Cat 994, Shovels and Excavators).

Tonnes material moved by the Truck and Shovel operation is an ideal measure of the work performed. This operation also consumes the bulk of the mine’s fuel. Short-term variations do occur as operations shift from one pit to another. However, over a twelve month period operating variables tend to average out making an assessment of Tonnes/L a reliable indicator.

***R**esults & **C**omments*

Table 1
Operating Data and Fuel Efficiency Improvements with FTC Combustion Catalyst

Month	Tonnes Shifted	Total Mine Litres	Truck & Shovel Hours	Fuel Efficiency (Tonnes/L)
UNTREATED				
Nov 01	1,305,505	727,281	3,391	1.795
Dec 01	1,145,068	613,581	2,905	1.866
Jan 02	1,460,108	788,142	3,670	1.853
Feb 02	1,387,647	778,900	3,647	1.782
Mar 02	1,454,893	813,383	3,677	1.789
Apr 02	2,227,180	1,012,533	5,008	2.200
May 02	2,311,594	1,109,238	5,501	2.084
Jun 02	2,428,367	938,872	5,063	2.586
Jul 02	2,496,742	1,075,184	5,218	2.322
Aug 02	2,484,820	1,042,881	5,116	2.383
Sep 02	2,043,636	945,531	4,774	2.161
Oct 02	2,182,634	1,029,127	5,257	2.121
TOTAL/AVERAGE	**22,928,192**	**10,874,653**	**53,227**	**2.261**
TREATED				
Nov 02	2,202,238	930,165	5,164	2.368
Dec 02	2,315,010	918,381	5,204	2.521
Jan 03	3,125,380	1,298,806	6,241	2.406
Feb 03	2,355,122	1,019,842	5,350	2.309
Mar 03	3,079,660	1,127,944	7,008	2.730
Apr 03	2,993,511	1,186,641	7,302	2.523
May 03	3,169,110	1,620,389	7,232	1.956
Jun 03	3,205,708	1,365,667	7,188	2.347
Jul 03	3,170,397	1,401,115	7,077	2.263
Aug 03	3,508,158	1,350,919	7,732	2.597
Sep 03	3,398,650	1,333,214	7,355	2.549
Oct 03	3,931,654	1,655,849	7,670	2.374
TOTAL/AVERAGE	**36,454,600**	**15,208,932**	**80,523**	**2.450**
% CHANGE	**59**	**40**	**51**	**8.3**

Table 1 quantifies the increased mine production (in terms of tonnes of material moved) achieved in the twelve month treated period. Clearly the volume of fuel consumed by the mine has not increased in line with the material moved.

The overall efficiency improvement indicated by this date is 13.7%. However, it is somewhat exaggerated by the figures for Nov '01 to Mar '02 when the mine operated a 5 day shift. The change to a 7-day shift was accompanied by increased operating efficiency. In addition, an excavator sidecasting operation was undertaken in May '03. The sidecast tonnages were not recorded producing an error for May '03. Consequently, the figures for Nov '01 to Mar '02 and May '03 were removed to achieve a valid comparison.

The operating data has confirmed an **8.3% fuel saving during the 12 month treated period** during which a total of 15,208,932 litres of diesel were consumed.

Table 2.
Fuel and Cost Savings with FTC Combustion Catalyst

% Fuel Saving	**8.3%**
Actual fuel used	**15,208,932 L (= 91.7%)**
Fuel saved	**1,376,599 L**
Value of fuel saved @ 40c/L	**$550,640**

Table 2 quantifies the fuel usage reduction achieved during the treated period. Without FTC fuel treatment the projected fuel use would have been 16,584,531 L. **Over 1.3 million litres of diesel were saved**. Assuming the average net fuel cost was 40 cents per litre, the operating cost reduction for the 12 month period was approximately **$550,000**.

Environmental Benefits

Energy savings are, of course, accompanied by reductions in Greenhouse Gas emissions of the same order. For 1,376,599 L diesel saved the reduction in CO_2 emitted is calculated by the Electricity Supply Business Greenhouse Change Workbook formula below.

Greenhouse Gas Reduction = (1,376,599 x 38.6 x 74.9)/1,000,000 Tonnes CO_2
= 3,980 Tonnes CO_2

Figure 1

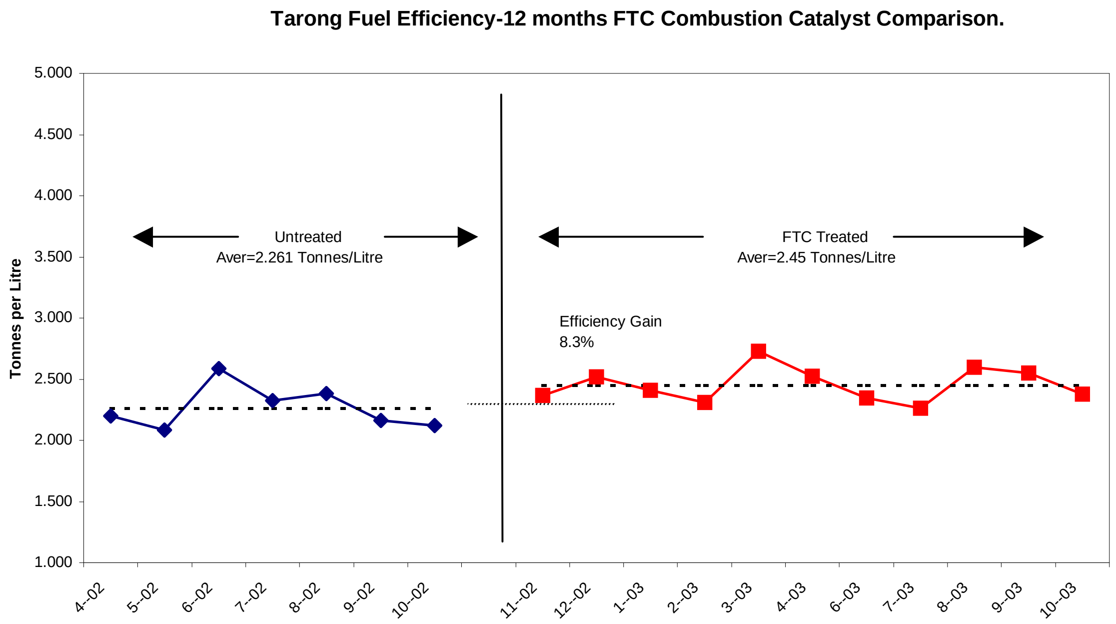

Figure 1 - Graphically displays the monthly fuel efficiency of the truck and shovel operation for the untreated and treated periods. NOTE that data for the 5 day shift operation and for May '03 (Tonnes Shifted were understated due to a sidecasting operation) were removed to enable a valid comparison.

Discussion &Conclusions

Mining operations generally vary from month to month especially when moving from one pit to another and for this reason fuel consumption can also vary over the short term. However, over a longer period these effects can be expected to average out. A study comparing the first 12 months operation of FTC Combustion Catalyst treated fuel with the period untreated 12 months was undertaken. The purpose was to quantify the fuel savings that were identified in a controlled two truck trial and also in the six month operating data.

During this 24 month study period mine output increased. During the treated 12 month period material shifted increased by 59%, major plant operated hours increased by 51% but fuel consumed increased by only 40%. As a measure of fuel efficiency Tonnes/litre had increased by 13.7%.

However, there was a clear efficiency improvement when operations changed from a 5 day to a 7 day shift. The former data had to be deleted from the comparison. Similarly the Tonnes Shifted for May ’03 considerably understated the work performed since there was a large shovel sidecasting operation performed which could not be quantified. May ’03 was also deleted from the comparisons. The remaining data was regarded as being representative of normal operations.

Analysis of the data determined an **8.3% fuel efficiency** (and consequently a Greenhouse benefit). On this basis a total of **1,376,599 litres of diesel were saved** during the treated period. This amounts to an operating **cost reduction of $550,640** for the 12 month period.

Due to the reduced diesel usage Greenhouse Gas emissions were reduced by a total of 3980 Tonnes of CO_2.

SOUTHWEST RESEARCH INSTITUTE

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EVALUATION OF A FUEL ADDITIVE

FINAL REPORT

Volume I

SwRI Project No. 03-4810

Prepared for:
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Prepared by:
Vernon O. Markworth

July 1992

Approved:

Shannon Vinyard, Director
Department of Engine Research

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INTRODUCTION

The UHI Corporation (UHI) FPC-1 Diesel Fuel Catalyst was evaluated according to Association of American Railroads (AAR) Recommended Procedure RP-503. This procedure consists of four phases:

Phase I - Fuel Property Tests
Phase II - Caterpillar 1G2 Engine Tests
Phase III - Two-cylinder EMD 567 Engine Tests (optional)
Phase IV - Twelve-cylinder EMD 645E3B Engine Tests

The FPC-1 fuel catalyst was subjected to Phases I, II, and IV while the optional Phase III was eliminated. Appendix F contains a detailed description of RP-503.

SUMMARY AND CONCLUSIONS

Phase I - Chemical Laboratory Evaluations

The FPC-1 was mixed in a diesel fuel at a concentration of 1/5000 (by volume) as recommended by UHI. When compared to the same diesel fuel without the additive, all measured properties were virtually identical with only minor variations that are considered insignificant and attributable to experimental error. FPC-1 thus had no measurable effect on the chemical properties of the fuel.

Phase II - Caterpillar 1G2 Engine Tests

This test provided a preliminary evaluation of the effect of the additive on overall engine performance, deposits, and wear before testing in the full-size locomotive engine. Under the specific conditions of these tests, the amount of carbon and lacquer in the piston grooves and lands indicated no harmful effects are produced by the additive relative to the baseline test. The difference between the baseline test results and the treated fuel results are within test-to-test repeatability. The percent of top ring groove fill due to carbon for the additive test was within the acceptability range for this procedure and virtually identical to the baseline test. None of the rated or measured engine parameters differed significantly between the baseline and treated fuel tests.

Phase IV – Twelve-Cylinder EMD 645E3B Engine Tests

This phase consisted of a 40 hour test on the baseline fuel, 200 hour preconditioning period on the treated fuel and a 40 hour test on the treated fuel. Statistical analysis of the data showed a BSFC improvement of 1.74 percent at a 95% confidence level with the FPC-1 treated fuel at a 1/5000 concentration by volume. Several factors complicated the data comparison. Each time a durability segment was started, the BSFC improved with time. During the first 40 hour segment on the baseline fuel the BSFC values improved just over 1 percent with durability accumulation. The BSFC also improved over 1 percent through 130 hours of the FPC-1 preconditioning period before it finally stabilized. The 40 hour segment on the FPC-1 catalyst also showed a downward trend of just under 1 percent in BSFC. The EMD generator apparently takes a considerable amount of time to come up to temperature and stabilize and there is no known correction factor to compensate for this. Ambient air temperature also affected the measured BSFC even though power output was corrected for ambient conditions. A constant generator efficiency was used in all power calculations but it appears that the generator efficiency changes with ambient temperature and it would be preferable (although impractical) to have a constant ambient air temperature in the test cell. The effect of air temperature was minimized by starting and stopping the 40 hour segments at the same clock time.

Exhaust emissions were unaffected by the FPC-1 catalyst at the 1/5000 concentration. While the statistical data shows an improvement in fuel economy, there is lack of engineering data from this test procedure to explain the reasons for these results. In order to understand the nature of the improvements, SwRI recommends conducting tests measuring combustion rates via combustion pressures using a high-speed data acquisition system. This will allow investigation into how combustion is changed, without the masking effects of engine friction and generator performance from changing ambient air temperatures. We do not dispute the test results, but neither do we understand the reason for the BSFC improvement without an impact in emissions.

TEST SETUP AND PROCEDURE

Phase I - Chemical Laboratory Evaluations

A sample of Type 2D diesel fuel was analyzed before and after addition of FPC-1 catalyst for standard diesel fuel properties. The concentration level specified was 1/5000, by volume. All chemical testing was performed according to standard American Society of Testing and Materials (ASTM) procedures with the exception of nitrate compound determination. The procedure for nitrate compound determination is specified in RP-503.

Phase II - Caterpillar 1G2 Engine Tests

The Caterpillar 1G2 engine tests were conducted to determine the effect of the FPC-1 treatment on piston ring sticking, power assembly wear (ring, liner, ring groove), and accumulation of combustion deposits. A baseline test was run with no additive in the diesel fuel using a reference oil in the crankcase. This was followed by an identical test with new reference oil except that the catalyst was mixed into the baseline fuel at a concentration of 1/5000 by volume.

The engine is a single-cylinder supercharged 4-stroke diesel cycle with a 5.12 inch bore and a 6.50 inch stroke. Tests were performed according to ASTM Procedure STP 509A. This procedure specifies precise limits on a number of parameters with the engine operating for 480 hours at 1800 rpm and a fuel energy input of 5850 BTU/min. Combustion air temperature is controlled at 255 °F with a humidity of 125 grains/pound. Additional operational controls are detailed on the Operational and Measurement Summary page of the test reports in Appendix A.

Phase IV - Twelve-Cylinder EMD 645E3B Engine Tests

The FPC-1 Diesel Catalyst was next tested in the EMD 645E3B laboratory engine located at SwRI. Specifications of this engine are shown in Table 1. The engine is fitted with a governor that facilitates laboratory testing by allowing infinite control of engine speed and load rather than only 8 notches as in the locomotive. The engine was completely instrumented to measure all pertinent parameters. Intake air, exhaust, cooling, and lubricating oil system pressures and temperatures were recorded in addition to engine speed, power output, and fuel consumption. Power generated by the engine was dissipated by a set of locomotive load grids. The cooling system was composed of six locomotive radiators and a thermostatically-controlled variable-pitch turbine fan maintained the required engine coolant temperature. Engine fuel consumption was measured by a Micromotion mass flowmeter. Engine performance figures were corrected to EMD standard conditions of 60° F inlet air temperature and 28.86 in-Hg barometric pressure. Approximate accuracies of the instruments used are shown in Table 2.

Table 1. Test Engine Specifications

	EMD 12-645 E3B
Type	2-stroke diesel, turbocharged
Bore (in.)	9-1/16
Stroke (in.)	10
Displacement (cu. in./cyl.)	645
No. of Cylinders	12
Compression Ratio	14.4
Injector System	Unit Injector
Rated Brake Horsepower (at flywheel)	2500
Rated Speed (rpm)	904
Power Absorption	EMD Generator

Table 2. Approximate Equipment Accuracies	
Fuel Flowmeter	± 0.4% of reading
Generator Voltage	± .01% of reading
Generator Current	± .01% of reading
Fluid Temperatures	± 0.6°F
Fluid Pressures	± 1%

The Phase IV 12-cylinder engine test consisted of two 40 hour segments and a 200 hour segment with all testing completed on the same batch of diesel fuel. The first 40 hours of testing were performed on the baseline diesel fuel and then followed by 200 hours of preconditioning on the same fuel with FPC-1 added. During the first 100 hours of preconditioning, FPC-1 was mixed at a concentration of 1/4000 by volume while during the second 100 hours of preconditioning, FPC-1 was mixed at a concentration of 1/5000. The second 40 hour segment followed the 200 hour preconditioning and was performed with the same fuel treated with FPC-1 mixed at 1/5000. All segments were controlled to a constant engine speed of 904 rpm with a fuel rate of 872 lb/hr that is equivalent to Notch 8 operation. Any improvement in fuel efficiency thus resulted in an increase in power output rather than a decrease in fuel consumption as would occur in a locomotive. Operation was on a 24 hour/day basis. The baseline and treated fuel 40-hour test segments were started at the same time of the day to minimize the effects of ambient condition variation. Engine performance data was recorded every 30 minutes throughout all testing.

Exhaust emissions were measured after completion of the 40 hours of operation on both the baseline diesel fuel and the FPC- 1 treated fuel. The engine was maintained at the same operating conditions, as during the durability segments, while the instruments were calibrated. This was followed by four consecutive steady-state measurements of the contaminants of interest. Unburned hydrocarbons were measured by a flame ionization detector meeting the requirements of Society of Automotive Engineers (SAE) Recommended Practice J215. Carbon dioxide and carbon monoxide were measured with non-dispersive infrared analyzers in a system conforming to SAE Recommended Practice 1177. Oxides of nitrogen were measured with a chemiluminescent analyzer that meets the requirements of SAE J177. Exhaust particulate measurements were made with a "split-then dilute" system wherein a portion of the exhaust flow was directed into a dilution tunnel and mixed with filtered, ambient air. Mixing occurs in the dilution tunnel prior to sampling the mixture for particulate. The tunnel is 8 inches in diameter and 15 feet long. Samples of particulate were collected on dual Pallflex T60A20 fluorocarbon-coated glass fiber filters. The temperature of the diluted exhaust stream at the entrance to the particulate sample probe was regulated to 123-125°F by varying the amount of raw exhaust entering the tunnel. All particulate filters were conditioned and weighed in a temperature-and humidity-controlled chamber both before and after use.

RESULTS

Phase I - Chemical Laboratory Evaluations

Samples of baseline diesel fuel and the same fuel treated with FPC-1 were analyzed; thus, any variation in fuel properties would be caused by the additive. The results of the chemical analysis of the baseline and FPC-1 treated diesel fuels are presented in Table 3. The measured parameters showed either no change or if there was a change, the differences are considered to be minimal or within test-to-test repeatability. Although accelerated stability increased from 0.5 to 1.0, this is negligible since diesel fuels with up to 1.5 are considered acceptable. Particulate contamination increased slightly from 4.8 to 5.9 mg/l but again this is minimal.

Phase II - Caterpillar 1G2 Evaluations

Tabulated in Appendix A is a summary of the results of the two 480 hour 1G2 tests, graphs of the operating conditions observed during the tests, and an analysis of the diesel fuel used in both tests. The data presentation format employs the following terms and abbreviations:

Deposit Types

Carbon:

HC	=	heavy carbon
MHC	=	medium-heavy (not rated)
MC	=	medium carbon
LC	=	light carbon
LCC	=	very light (not rated)

Lacquer:

BL	=	black lacquer
DBRL	=	dark brown
AL	=	amber
LAL	=	light amber
VLA	=	very light amber
RL	=	rainbow (multi-colored)

Weighting Factor

Dep. Fct. = deposit factor (varies with type of deposit)
Loc. Fct. = location factor (varies with deposit location)

Abbreviations

TWD	=	total weighted demerit
TGF	=	top (ring) groove fill
A,%	=	percent of area covered by deposit
Dem.	=	demerit
Un-crown	=	underside of piston crown

Conventions

- The total weighted demerit and the top groove fill are the most important of the piston deposit factors.

- "Supplemental Deposits" are considered to be of secondary importance compared to "Piston Deposits."

TABLE 3. Fuel Property Test Results			
Fuel Property	ASTM Procedure	Baseline Fuel	Baseline Fuel with FPC-1 at I./5000 Ratio
Gravity. API @ 60°F	D 287	31.9	31.9
Flash Point, °C	D 93	50	50
Cloud Point, °C	D 2500	-12	-12
Pour Point, °C	D 97	-15	-15
Kinematic Viscosity @ 100°P, CS	D 445	3.21	3.20
Distillation Range, °F	D 86		
IBP		348	348
10%		440	438.
20%		469	470
30%		493	492
40%		510	509
50%		526	524
60%		544	543
70%		563	563
80%		589	587
90%		619	619
EP		671	668
Carbon Residue, %	D 524	.16	.18
Sulfur, %	D 129	.33	.30
Copper Strip Corrosion	D 130	1a	la
Ash Content, %	D 482	<001	<001
Water Content. ppm	D 2709	105	78
Accelerated Stability	D 2274	.5	1.0
Neutralization Number	D 974	.006	.006
Particulate Contamination mg/l	D 2276	4.8	5.9
Caisson Number	D 613	45.2	45.7
Gross Heat of Combustion BTU/lb	D 240	19,341	19,343
Nitrate Determination		Negative	Negative

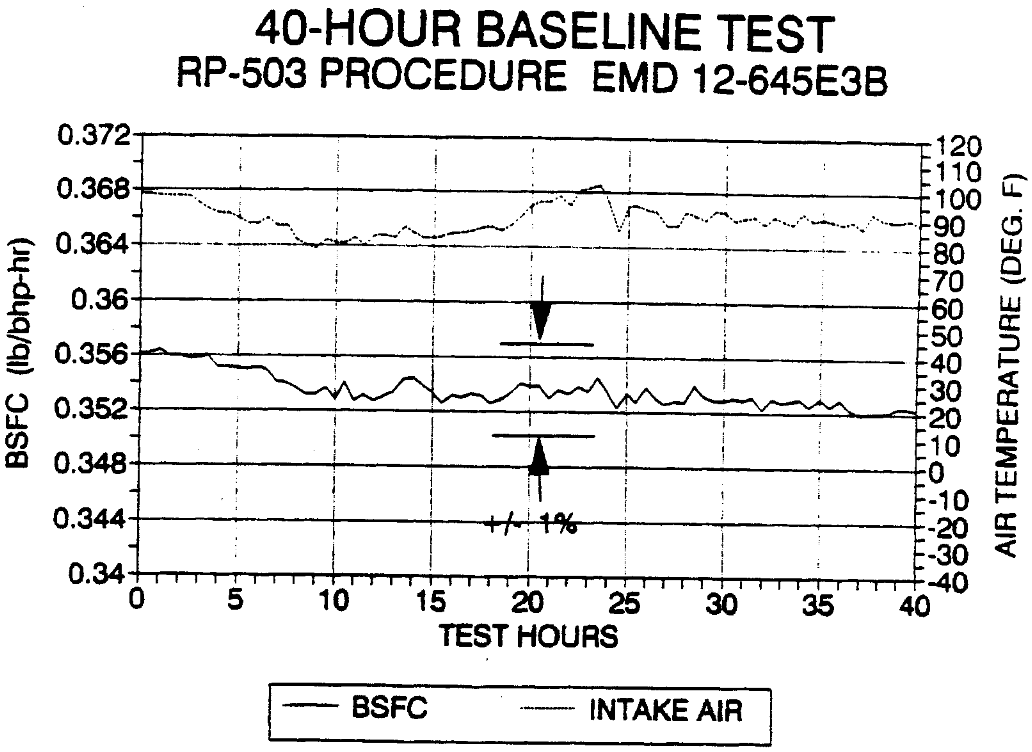
• No value entered (i.e., a blank space) means that no deposits were observed.

The first two pages of the summary are the results of the 120 hour piston inspection while the remainder of the summary shows the results of the end of test inspection at 480 hours. The total weighted demerit rating of the baseline fuel was 215.6 and for the treated fuel it was 223.7. The top groove filling was 67% and 74%, respectively.

Phase IV – Twelve-Cylinder EMD 645E3B Evaluations

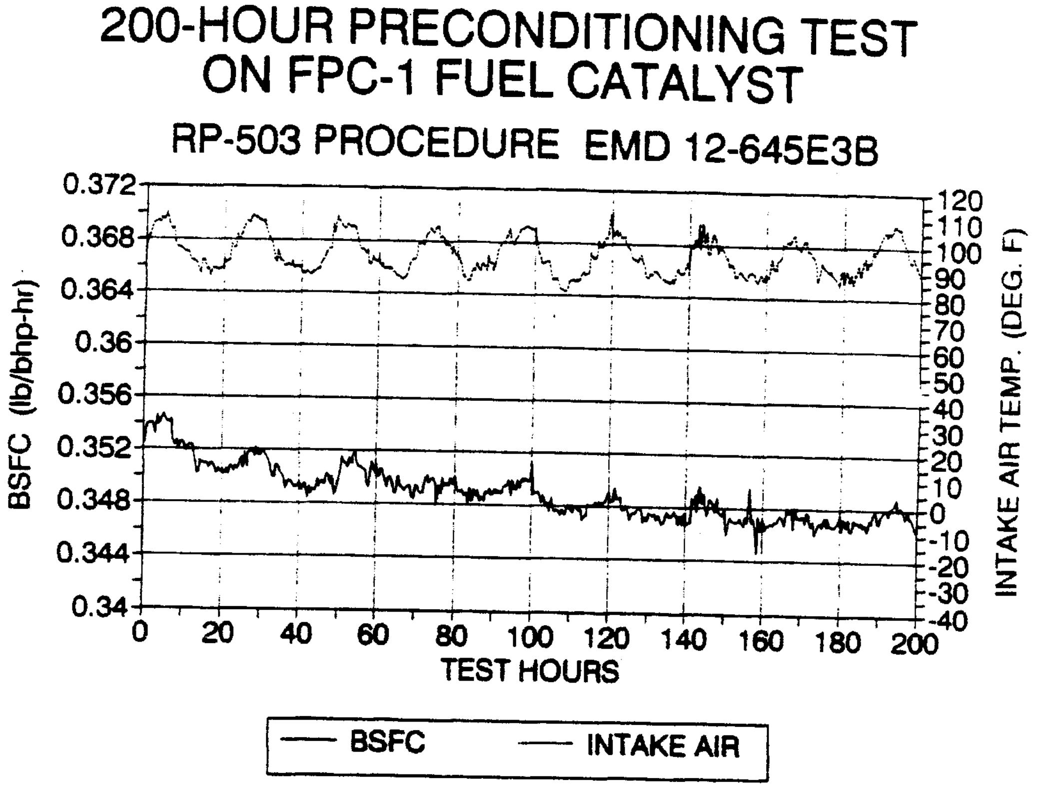
Appendix B contains all engine performance data acquired at 30 minute intervals during the three durability segments. The baseline 40 hour segment was completed without incident and Figure 1 shows the variation of BSFC and intake air temperature with test hours over this period. A 200 hour preconditioning period on two different concentrations of FPC-1 was then accomplished and Figure 2 displays these results. Results from the second 40 hour segment with FPC-1 are shown in Figure 3 and are compared to the baseline 40 hour segment in Figure 4. During all testing, the FPC-1 catalyst showed an improvement in BSFC over the baseline test. Even though all horsepower was corrected to standard ambient conditions, all three figures show a slight influence of intake air temperature on BSFC. Intake air temperature could not be controlled automatically but to make the tests as directly comparable as possible, both 40 hour segments were started and stopped at the same clock time. Exhaust smoke was measured during all segments but since the engine operated only at Notch 8 conditions, all values were extremely low and no smoke trends were detected. Low exhaust smoke at Notch 8 is typical for this laboratory engine.

A statistical analysis was next performed to evaluate the effects of the fuel catalyst on BSFC. Sixty sets of engine data were taken over a 5 minute interval during all testing and then averaged to provide a test point each 30 minutes. Data from the preconditioning test were not used in the comparative analysis. Although the averaged data points were collected in a sequential order for each test, carryover effects from one observation to the next were felt to be minimized by averaging the data. There still may be some bias due to the fact that the baseline and treated fuel were each tested at only one time interval (rather than at several different time periods) but the intermediate preconditioning period was used to minimize this possibility.



40-HOUR BASELINE TEST
RP-503 PROCEDURE EMD 12-645E3B
BSFC (lb/bhp-hr)
0.372
0.368
0.364
0.36
0.356
0.352
0.348
0.344
0.34
AIR TEMPERATURE (DEG. F)
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
0
5
10
15
20
25
30
35
40
TEST HOURS
+/- 1%
BSFC
INTAKE AIR

FIGURE 1



Note: 0-100 hours at 1/4000 concentration; 100-200 hours at 1/5000 concentration

FIGURE 2

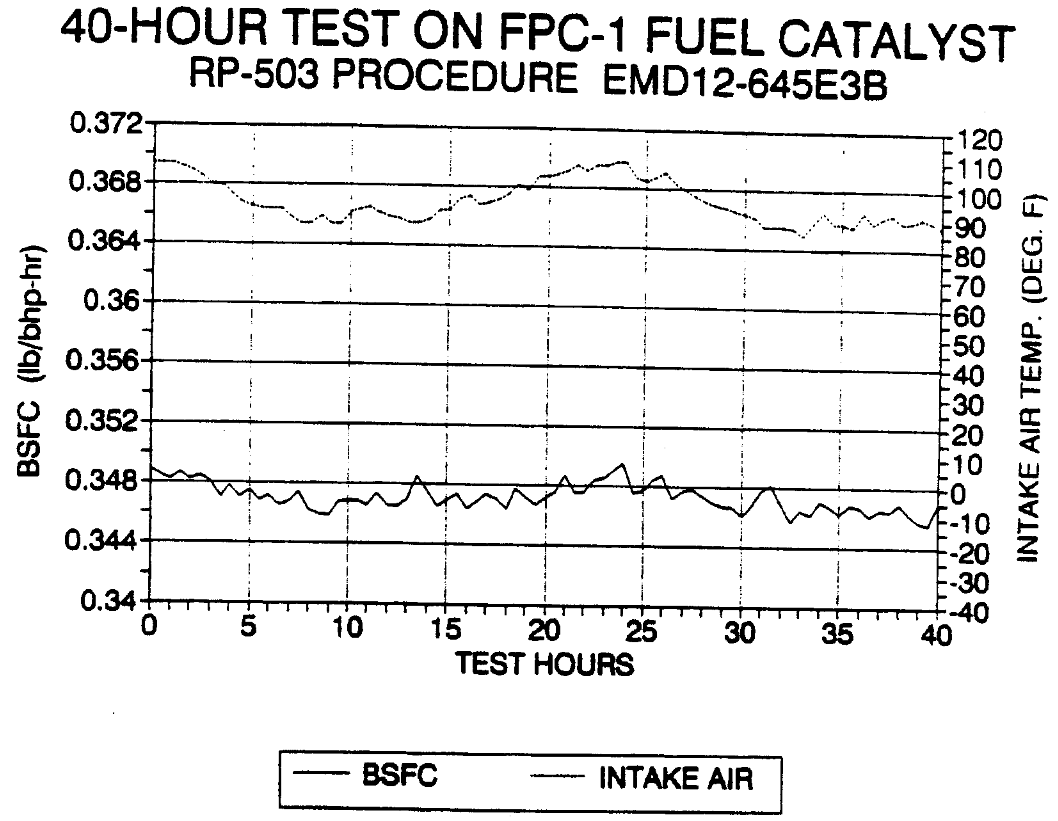

40-HOUR TEST ON FPC-1 FUEL CATALYST
RP-503 PROCEDURE EMD12-645E3B
BSFC (lb/bhp-hr)
0.372
0.368
0.364
0.36
0.356
0.352
0.348
0.344
0.34
INTAKE AIR TEMP. (DEG. F)
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
0
5
10
15
20
25
30
35
40
TEST HOURS
BSFC
INTAKE AIR

FIGURE 3

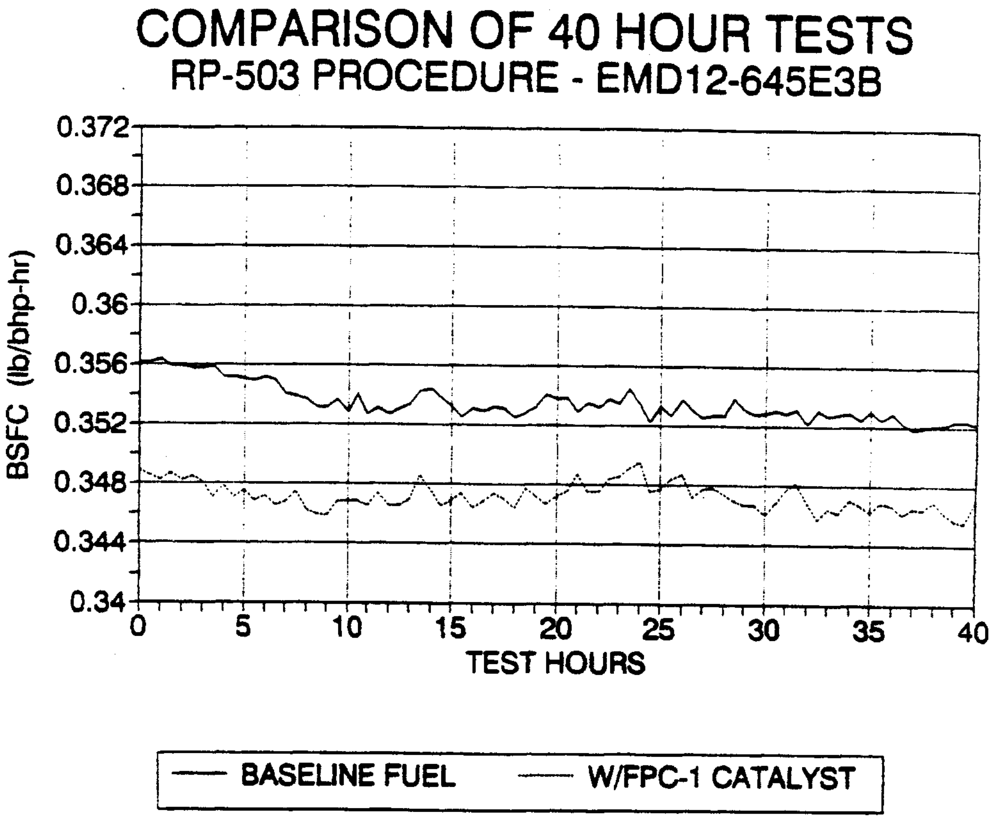

COMPARISON OF 40 HOUR TESTS
RP-503 PROCEDURE - EMD12-645E3B
BSFC (lb/bhp-hr)
0.372
0.368
0.364
0.36
0.356
0.352
0.348
0.344
0.34
0
5
10
15
20
25
30
35
40
TEST HOURS
BASELINE FUEL
W/FPC-1 CATALYST

FIGURE 4

It was assumed that the data were normally distributed. This assumption was checked using normal probability plots and histograms of the averaged data. The resultant plots are presented in Figures 5 through 8. The BSFC data appears to be normally distributed for the treated fuel but is non-normal and skewed to the right for the baseline data. A two-sample t-test was next used to compare the average BSFC for the two 40 hour segments. This test requires that the two data sets have similar variability and be normally distributed. The variability of the two data sets were similar with standard deviations of .00112 for the treated fuel and .00110 for the baseline fuel. It was felt that the non-normality of the baseline fuel test was not sufficient to effect the t-test and change the conclusions. This was confirmed by testing the data for significant differences using a non-normal two-sample Mann-Whitney test. The obtained results were similar to those using the t-test. In both cases, the BSFC for the treated fuel was found to be lower than for the baseline fuel.

Table 4. Statistical Results of BSFC Data

Percent Improvement	**95% Confidence Interval**	**Confidence Level At Which Percent Improvement Is Significant**
1.74	+/-0.099	99.9%
Fuel	**Average BSFC**	**Standard Deviation**
Baseline	0.3535	0.001124
FPC-1 Treated	0.3474	0.001099
Note: Percent Improvement = ((Baseline - Treated)/Baseline)) x 100		

Percent improvement in BSFC for the FPC-1 tested fuel over the baseline fuel and the resulting 95% confidence interval about this improvement is in Table 4 followed by the average and standard deviations of the BSFC values for each fuel.

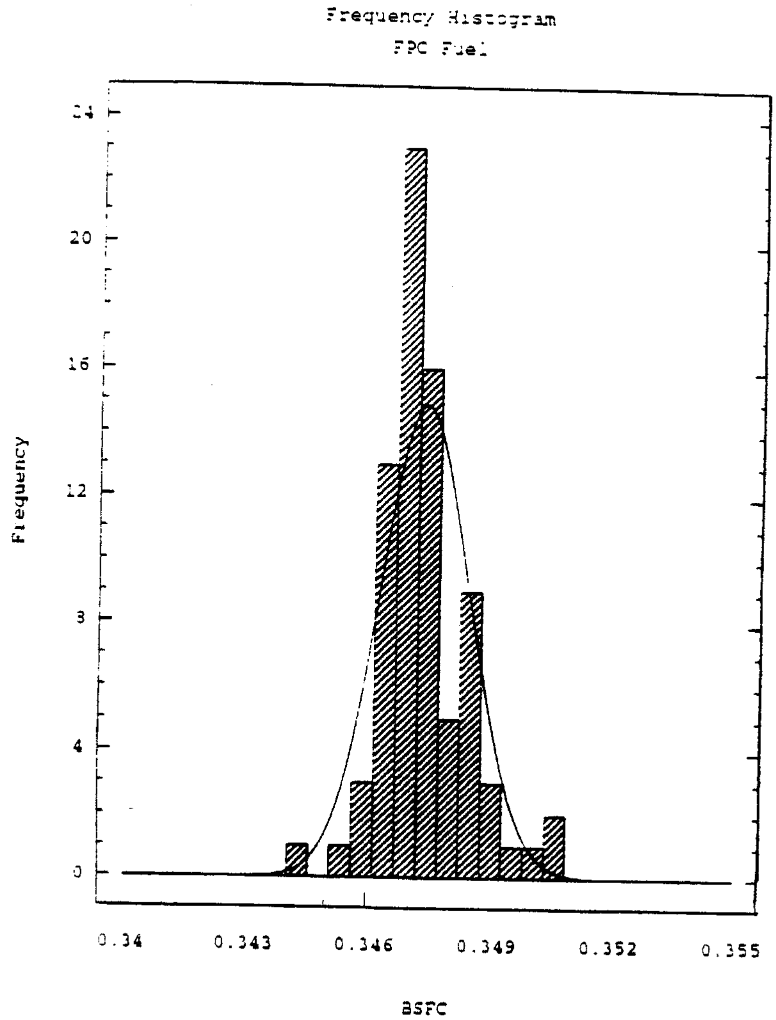
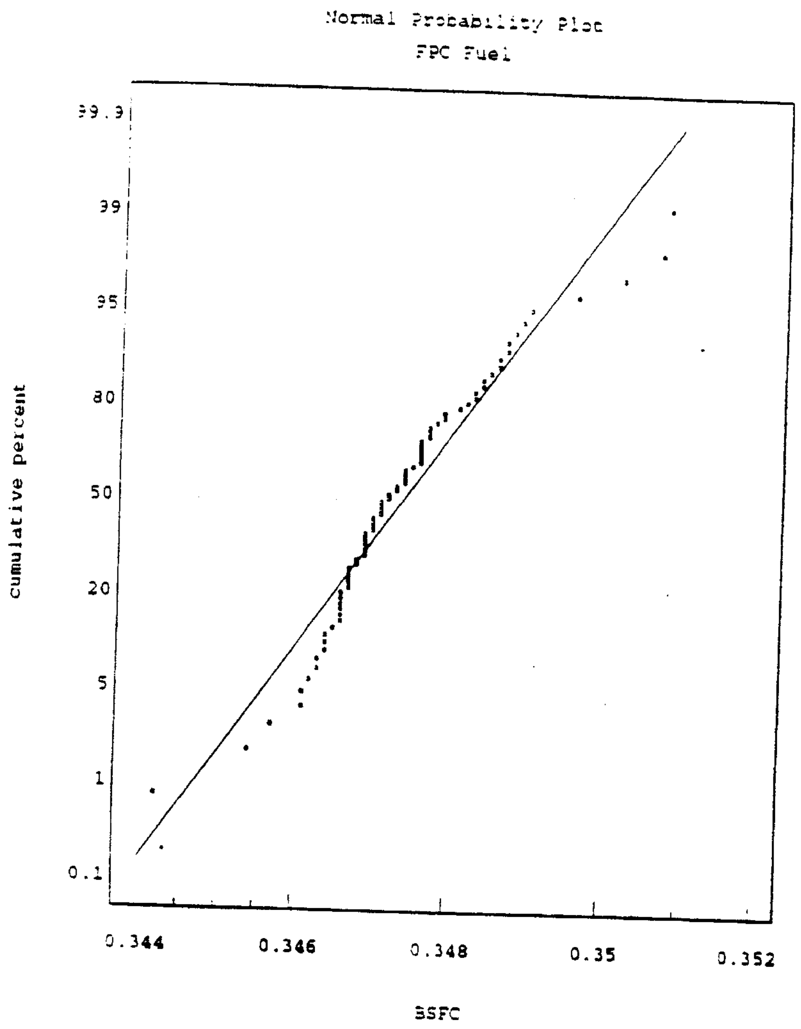

Frequency Histogram
FPC Fuel
Frequency
24
20
16
12
8
4
0
0.34
0.343
0.346
0.349
0.352
0.355
BSFC

FIGURE 5



Normal Probability Plot
FPC Fuel
99.9
99
95
80
50
20
5
1
0.1
cumulative percent
0.344
0.346
0.348
0.35
0.352
BSFC

FIGURE 6

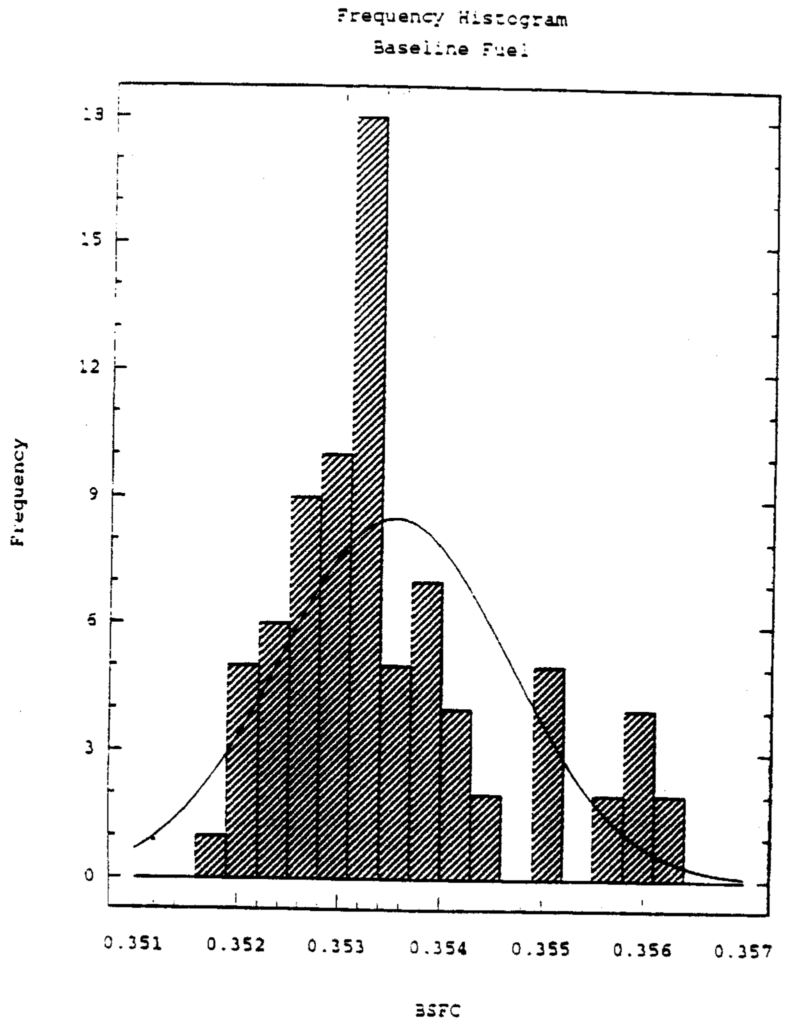

Frequency Histogram
Baseline Fuel
Frequency
18
15
12
9
6
3
0
0.351
0.352
0.353
0.354
0.355
0.356
0.357
BSFC

FIGURE 7

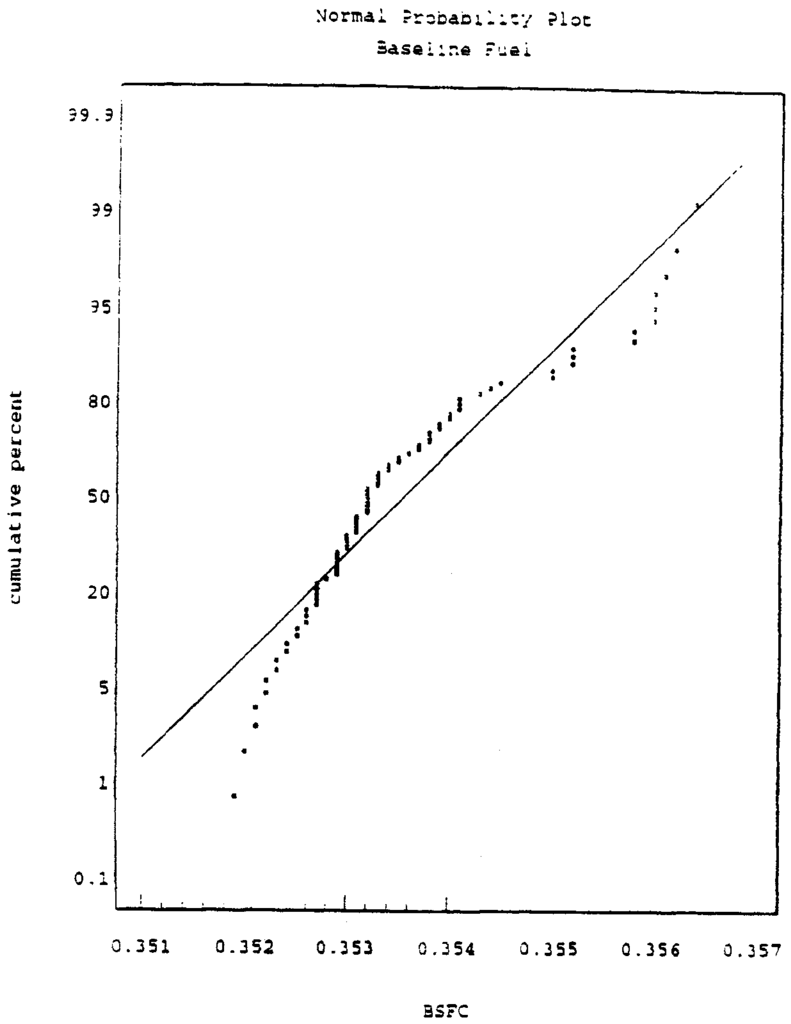

Normal Probability Plot
Baseline Fuel
cumulative percent
99.9
99
95
80
50
20
5
1
0.1
0.351
0.352
0.353
0.354
0.355
0.356
0.357
BSFC

FIGURE 8

Results of the exhaust emissions measured at the end of the two 40 hour segments are shown in Table 5 on a brake specific basis (g/bhp-hr) and the raw data is contained in Appendix E. The baseline and treated fuels produced almost identical results and any differences are within repeatability and/or experimental error.

Table 5. Exhaust Emission Comparison at Notch 8

	Baseline g/bhp-hr	FPC-1 Treated g/bhp-hr
HC	.22	.21
CO	.92	.86
NO_x	10.5	10.9
Particulates	.23	.25

Note: Average of 4 runs on each fuel

FPC Benefits in Combustion Engines