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EVALUATION OF FPC-1 FUEL PERFORMANCE CATALYST

AT

CHARLEY BROTHERS DIVISION
SUPER VALU RETAIL SUPPORT CENTER
NEW STANTON, PENNSYLVANIA

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July 21, 1989

Report No. LOTR 102R

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INTRODUCTION

FPC-1 is a complex combustion catalyst, which when added to liquid hydrocarbon fuels at a ratio of 1:5000 effectively improves the combustion reaction, resulting in increased engine efficiency and reduced fuel consumption.

Field and laboratory tests alike indicate a potential to reduce fuel consumption in diesel fleets in the range of 4% to 8%. This report summarizes the results of controlled back-to-back field tests conducted with the cooperation of the Charley Brothers Division, Super Valu Support Center in New Stanton, PA., with and without FPC-1 added to the fuel. The test procedures applied were the Carbon Balance Exhaust Emission Tests at a given load and engine speed.

ENGINES TESTED

The following engine makes were tested:

7 x Mack 300 engines

TEST EQUIPMENT

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, CO2, and O2.

An IMC High Temperature Digital Thermometer for measuring exhaust gas and ambient temperature.

A Hewlett Packard Model 41C programmable calculator for the calculation of the engine performance factors.

TEST PROCEDURE

The carbon balance technique for determining changes in fuel consumption has been recognized by the U.S. Environment Protection Agency (EPA) since 1973. 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 fuel consumption test method utilized in this study involves the measurement of exhaust gases of a stationary vehicle at a steady engine load and rpm. 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 exhaust and ambient temperature and pressure are made to perform appropriate corrections. Under these conditions a minimum of five readings were taken for each parameter after stabilization of the exhaust temperature. Seven trucks were tested for both baseline and treated fuel segments. Each truck was tested under steady-state conditions at 1800 and 1500 rpm. Table 1 below summarizes the results before correcting for changes in ambient temperature. Table 2 summarizes the results with the ambient temperature corrections.

Table 1.

Uncorrected

Unit No.	Engine	RPM	% Improvement
127	300 Mack	1800	7.05
		1500	9.81
122	300 Mack	1800	(0.89)♦
		1500	(0.55)♦
181	300 Mack	1800	5.01
		1500	5.88
114	300 Mack	1800	11.95
		1500	5.97
115	300 Mack	1800	12.18
		1500	17.41
185	300 Mack	1800	16.01
		1500	13.26
182	300 Mack	1800	3.10
		1500	(0.93)

♦ ( ) indicates negative change

Table 2.

Corrected

Unit No.	Engine	RPM	% Improvement
127	300 Mack	1800	3.41
		1500	5.66
122	300 Mack	1800	(4.26)
		1500	(4.12)
181	300 Mack	1800	1.85
		1500	2.38
114	300 Mack	1800	8.75
		1500	2.52
115	300 Mack	1800	8.78
		1500	13.46
185	300 Mack	1800	12.07
		1500	9.45
182	300 Mack	1800	0.00
		1500	(4.33)

The results indicate a general reduction in fuel consumption for the test fleet. The general trend of improved (reduced) fuel consumption is within the general parameters of reduced fuel consumption achievable by the use of FPC-1 Fuel Performance Catalyst.

DISCUSSION OF THE RESULTS AND CONCLUSION

Fuel Economy

The series of tests conducted on a number Mack 300 powered trucks operated by Charley Brothers confirm that the addition of FPC-1 to the fuel will reduce fuel consumption.

The percent improvement in fuel economy (reduced fuel consumption) in the mobile fleet at 1500 rpm is 7.26% (see Figure 1) The percent improvement at 1800 rpm is 7.78% (see Figure 2). The average improvement at both 1500 and 1800 rpm is 7.51%.

The mean for the fleet at 1500 rpm with ambient temperature corrected is 3.58% (see Figure 3). The mean for the fleet at 1800 with ambient temperature corrected is 4.39% (see Figure 4). The average improvement for both engine speeds after temperature correction is 3.98% (see Figure 5).

The Charley Brothers fleet demonstrated fuel economy improvements between 4% and 8% with the addition of FPC-1. Improvements seen at the higher engine speed of 1800 rpm are

likely to more indicative of fuel savings obtainable in actual fleet operation. The improvement is typical of highly efficient and well maintained fleets.

Filter Trap Comparison

The exhaust particulate (smoke) comparison test conducted by Charley Brothers revealed the test fleet produces less smoke with FPC-1 treated fuel. The photograph attached in the appendices compares the filter trap used to trap exhaust particulate during the baseline or untreated fuel test segment to the filter used to trap particulate during the FPC-1 treated fuel test segment. The baseline filter trap was subjected to baseline exhaust gas sampling for seventy-six (76) minutes. The FPC-1 treated fuel filter trap was subjected to the fleet's exhaust for ninety-three (93) minutes.

Softening of Carbon on Turbocharger

Recent repair work on equipment treated with FPC-1 has revealed a softening of the carbon buildup commonly seen on the exhaust side of the turbocharger. Maintenance personnel report that carbon deposits were harder prior to FPC-1 fuel treatment.

APPENDICES

CARBON BALANCE METHOD TECHNICAL APPROACH:

A fleet of diesel powered trucks owned and operated by the Charley Brothers Division, Super Valu Retail Support Center in New Stanton, PA., was selected for the FPC-1 evaluation. The SGA-9000 exhaust analyzer and the thermocouple instrumentation were calibrated and a leak test on the sampling hose and connections was performed. Each truck engine was then brought up to stable operating temperature as indicated by the engine water temperature and exhaust temperature. No exhaust gas measurements were made until each truck engine had stabilized at the operating condition selected for the test. No. 2 diesel fuel was exclusively used throughout the evaluation.

The baseline fuel consumption test consisted of five sets of measurements of CO_2, CO, unburned hydrocarbons (measured as hexane gas), O_2, and exhaust temperature, made at 60 to 90 second intervals for each engine test speed of 1800 rpm and 1500 rpm.

After the baseline test on April 13, 1989, the fuel storage tank, from which the fleet is exclusively fueled, was treated with FPC-1 at the recommended level of 1 oz. of catalyst to 40 gallons of diesel fuel (1:5000 volume ratio). The trucks were then operated with the treated fuel until July 20, 1989 when the fuel consumption test described above was repeated on each truck.

Throughout the entire fuel consumption test, an internal self-calibration of the exhaust analyzer was performed after every two sets of measurements to correct instrument drift. A new analyzer exhaust gas filter was installed before both the baseline and treated fuel test series.

Engine operating speeds of 1500 rpm and 1800 rpm were selected to demonstrate the correlation of the exhaust analysis with fuel consumption. Though the higher engine speed is more realistic, less fuel would be consumed by the engine operating at the lower speed for the same load. For a diesel engine with no air flow throttling, this will result in lower volumetric concentrations of carbon-containing exhaust gases, which can be observed from the measurements obtained from the exhaust analyzer during the evaluation.

From the exhaust gas concentrations measured during the test, the molecular weight of each constituent, the exhaust volume and the temperature of the exhaust stream, the fuel consumption may be expressed as a "performance factor" which relates the fuel consumption of the treated fuel to the baseline. The calculations are based on the assumption that the fuel characteristics, engine operating conditions and test conditions are essentially the same throughout the test.

Note: Approximately two months after the April 13th baseline segment of the above test, Mr. Ed Nusser discovered that the new oxygen sensor used during the Charley Brothers baseline was malfunctioning. Subsequently, he contacted Sun Electric and had the sensor adjusted and re-calibrated. Therefore, the oxygen (02) readings taken during baseline are erroneous and could not be used in this study. This is not a significant, however, as O2

percentage changes are usually small and have little bearing on the test results. For this reason, the treated fuel 02 values have been used for both baseline and treated carbon balance calculations.

The Sun Electric repair record is attached in the appendices.

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS UNIT NO. 127

EQUIPMENT: TRUCK
ENGINE: MACK MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 7,601
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.61	1.61	1.61	1.61	1.63	1.614
CO%	0.02	0.02	0.02	0.02	0.02	0.02
02%						19.12♦
HCppm	9.00	8.00	10.00	10.00	10.00	9.40
EXHST. TEMP. (F)	274	275	279	280	282	278
** EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦TREATED O2%
♦♦CONSTANT

TREATED **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 33,563
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.59	1.59	1.57	1.57	1.60	1.584
CO%	0.02	0.02	0.02	0.02	0.02	0.02
02%	19.10	19.10	19.20	19.10	19.10	19.12
HCppm	15.00	15.00	15.00	15.00	15.00	15.00

EXHST. TEMP. (F)	315	316	317	318	318	316.8
♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS — UNIT NO. 122

EQUIPMENT: TRUCK
ENGINE: MACK — MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE — **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 12,870
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	AVE.
CO2%	1.55	1.57	1.58	1.58	1.58
CO%	0.02	0.02	0.02	0.02	0.02
02%					18.56♦
HCppm	10.00	10.00	9.00	9.00	9.33
EXHST. TEMP. (F)	272	272	273	273	272.7
♦♦ EXHST. VOLUME(CFM)	630	630	630	630	630

♦ TREATED 02%
♦♦ CONSTANT

TREATED **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 43,082
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.64	1.63	1.66	1.66	1.66	1.65
CO%	0.02	0.02	0.02	0.02	0.02	0.02
02%	18.60	18.50	18.50	18.40	18.40	18.56
HCppm	13.00	13.00	13.00	13.00	14.00	13.20
EXHST. TEMP. (F)	299	299	299	299	299	299.0
♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS UNIT NO. 181

EQUIPMENT: TRUCK
ENGINE: MACK MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 334,154
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.97	1.97	1.94	1.92	1.92	1.944
CO%	0.04	0.04	0.04	0.04	0.04	0.040
02%						18.20♦
HCppm	9.00	9.00	9.00	9.00	10.00	9.20

EXHST. TEMP. (F)	309	309	311	312	13	310.8
♦♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ TREATED 02%
♦♦ Corrected

TREATED **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 361,725
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	2.01	1.99	2.00	1.99	1.99	1.996
CO%	0.02	0.02	0.02	0.02	0.02	0.020
02%	18.30	18.00	18.20	18.20	18.30	18.20
HCppm	18.00	18.00	19.00	19.00	18.00	18.40
EXHST. TEMP. (F)	365	366	366	365	363	365.0
♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS UNIT NO.114

EQUIPMENT: TRUCK
ENGINE: MACK MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 129,936
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 51 F

BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	2.20	2.19	2.18	2.16	2.19	2.184
CO%	0.05	0.05	0.05	0.05	0.05	0.050
02%						18.02♦
HCppm	10.00	10.00	14.00	14.00	12.00	12.00
EXHST. TEMP. (F)	318	320	328	328	330	324.8
♦♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ TREATED 02%
♦♦ CONSTANT

TREATED **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 155,301
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	2.09	2.09	2.11	2.11	2.09	2.098
CO%	0.03	0.03	0.03	0.03	0.03	0.030
02%	18.10	17.90	18.00	17.70	18.40	18.02
HCppm	15.00	15.00	18.00	18.00	18.00	16.80
EXHST. TEMP. (F)	380	380	380	380	379	379.8
♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS — UNIT NO. 115

EQUIPMENT: TRUCK
ENGINE: MACK — MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE — **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 147,700
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	2.13	2.13	2.13	2.12	2.12	2.13
CO%	0.04	0.04	0.04	0.04	0.04	0.04
02%						18.6♦
HCppm	14.00	14.00	13.00	13.00	12.00	13.2
EXHST. TEMP. (F)	321	322	325	325	328	324.2
♦♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ TREATED 02%
♦♦ CONSTANT

TREATED — **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 174,990
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	2.02	2.01	2.02	2.09	2.00	2.028
CO%	0.02	0.02	0.02	0.02	0.02	0.020
02%	18.70	18.50	18.70	18.50	18.60	18.60
HCppm	15.00	17.00	17.00	16.00	17.00	16.40

EXHST. TEMP. (F)	370	371	373	374	376	372.8
♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS — UNIT NO. 185

EQUIPMENT: TRUCK
ENGINE: MACK — MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE — **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 411,547
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.99	1.99	1.96	1.96	1.93	1.966
CO%	0.04	0.04	0.04	0.04	0.04	0.040
02%						18.71♦
HCppm	8.00	8.00	8.00	8.00	8.00	8.00
EXHST. TEMP. (F)	321	321	322	322	321	321.4
♦♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ TREATED 02%
♦♦ CONSTANT

TREATED **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 436,100
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.76	1.77	1.77	1.73	1.74	1.754
CO%	0.03	0.03	0.02	0.02	0.02	0.024
02%	18.80	18.70	18.80	18.70	18.90	18.71
HCppm	18.00	17.00	19.00	17.00	18.00	17.80
EXHST. TEMP. (F)	347	347	348	348	350	348.0
♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS UNIT NO. 182

EQUIPMENT: TRUCK
ENGINE: MACK MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE **DATE: APR. 13, 1989**

ENGINE MILES (HRS.): 339,074
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.99	1.97	1.94	1.93	1.93	1.952
CO%	0.03	0.03	0.03	0.03	0.03	0.030
02%						18.16♦
HCppm	10.00	11.00	14.00	14.00	13.00	12.40

EXHST. TEMP. (F)	318	319	324	325	328	322.8
♦♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ TREATED 02%
♦♦ CONSTANT

TREATED **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 364,295
ENGINE SPEED: 1800 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	2.01	2.02	2.02	2.04	2.02	2.022
CO%	0.02	0.02	0.02	0.02	0.02	0.020
02%	18.10	18.00	18.40	18.00	18.30	18.16
HCppm	16.00	17.00	19.00	19.00	19.00	18.00
EXHST. TEMP. (F)	381	380	377	376	374	377.6
♦ EXHST. VOLUME(CFM)	630	630	630	630	630	630

♦ CONSTANT

Table 3

MOLECULAR WEIGHT OF EXHAUST GASES, ENGINE PERFORMANCE FACTORS AND FUEL ECONOMY IMPROVEMENTS AT 1800 RPM

Unit No. 127

Mwt1	29.0238	Mwt2	29.0195
pf1	376,000	pf2	382,000
PF1	440,000	PF2	471,000
		PF2	455,000♦

% Improvement F.E. = [(471,000 - 440,000)/440,000](100)

% Improvement F.E. = + 7.05%

(♦ Corrected % Improvement F.E. = + 3.41%)

Unit No. 122

Mwt1	28.9960	Mwt2	29.0075
pf1	383,000	pf2	367,000
PF1	446,000	PF2	442,000
		PF2	427,000♦

% Improvement F.E. = [(442,000 - 446,000)/446,000](100)

% Improvement F.E. = - .89%

(♦ Corrected % Improvement F.E. = - 4.26%)

Unit No. 181

Mwt1	29.0398	Mwt2	29.0489
pf1	310,000	pf2	304,000
PF1	379,000	PF2	398,000
		PF2	386,000♦

% Improvement F.E. = [(398,000 - 379,000)/379,000](100)

% Improvement F.E. = + 5.01%

(♦ Corrected % Improvement F.E. = 1.85%)

Unit No. 114

Mwt1	29.0712	Mwt2	29.0579
pf1	275,000	pf2	288,000
PF1	343,000	PF2	384,000
		PF2	373,000♦

% Improvement F.E. = [(384,000 - 343,000)/343,000](100)

% Improvement F.E. = + 11.95%

(♦ Corrected Improvement F.E. = + 8.75%)

Unit No. 115

Mwt1	29.0859	Mwt2	29.0698
pf1	284,000	pf2	300,000
PF1	353,000	PF2	396,000
		PF2	384,000♦

% Improvement F.E. = [(396,000 - 353,000)/353,000](100)

% Improvement F.E. = + 12.18%

(♦ Corrected Improvement F.E. = + 8.78%)

Unit No. 185

Mwt1	29.0664	Mwt2	29.0333
pf1	307,000	pf2	344,000
PF1	381,000	PF2	442,000
		PF2	427,000♦

% Improvement F.E. = [(442,000 - 381,000)/381,000](100)

% Improvement F.E. = + 16.01%

(♦ Corrected Improvement F.E. = + 12.07%)

Unit No. 182

Mwt1	29.0387	Mwt2	29.0514
pf1	311,000	pf2	300,000
PF1	387,000	PF2	399,000
		PF2	387,000♦

% Improvement F.E. = [(399,000 - 387,000)/387,000](100)

% Improvement F.E. = + 3.10%

(♦ Corrected Improvement F.E. = 0%)

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS — UNIT NO. 127

EQUIPMENT: TRUCK
ENGINE: MACK — MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE — **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 7,601
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.41	1.41	1.41	1.41	1.42	1.412
CO%	0.02	0.02	0.02	0.02	0.02	0.020
02%						19.24♦
HCppm	9.00	10.00	10.00	10.00	10.00	9.80
EXHST. TEMP. (F)	262	261	258	257	257	259.0
♦♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ TREATED 02%
♦♦ CONSTANT

TREATED — **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 33,569
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.35	1.35	1.32	1.32	1.33	1.334
CO%	0.02	0.02	0.02	0.02	0.02	0.020
02%	19.40	19.30	19.10	19.10	19.30	19.24
HCppm	16.00	16.00	16.00	16.00	16.00	16.00

EXHST. TEMP. (F)	288	288	287	286	287	287.20
♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS UNIT NO. 122

EQUIPMENT: TRUCK
ENGINE: MACK MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 12,870
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.39	1.38	1.39	1.39	1.40	1.390
CO%	0.02	0.02	0.02	0.02	0.02	0.020
02%						18.90♦
HCppm	10.00	10.00	9.00	9.00	9.00	9.40
EXHST. TEMP. (F)	254	253	251	252	252	252.4
♦♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ TREATED 02%
♦♦ CONSTANT

TREATED **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 43,082
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.46	1.44	1.45	1.45	1.45	1.450
CO%	0.02	0.02	0.02	0.02	0.02	0.020
02%	19.20	18.80	18.90	18.90	18.70	18.90
HCppm	14.00	14.00	15.00	14.00	14.00	14.20
EXHST. TEMP. (F)	282	280	279	278	279	279.6
♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS UNIT NO. 181

EQUIPMENT: TRUCK
ENGINE: MACK MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 334,154
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.67	1.66	1.66	1.66	1.66	1.662
CO%	0.04	0.04	0.04	0.04	0.04	0.040
02%						18.56♦
HCppm	12.00	11.00	10.00	10.00	11.00	11.00
EXHST. TEMP. (F)	285	283	281	281	281	282.2
♦♦ EXHST. VOLUME CFM)	425	425	425	425	425	425

♦ TREATED 02%
♦♦ CONSTANT

TREATED **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 361,725
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.67	1.67	1.66	1.66	1.66	1.662
CO%	0.02	0.02	0.02	0.02	0.02	0.020
02%	18.50	18.60	18.60	18.60	18.50	18.56
HCppm	22.00	22.00	23.00	23.00	22.00	22.40
EXHST. TEMP. (F)	322	321	320	320	318	320.2
♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS UNIT NO. 114

EQUIPMENT: TRUCK
ENGINE: MACK MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 129,936
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.64	1.67	1.63	1.64	1.66	1.648
CO%	0.03	0.03	0.03	0.03	0.03	0.030
02%						18.70♦
HCppm	10.00	9.00	10.00	10.00	10.00	9.80

EXHST. TEMP. (F)	282	281	278	277	274	278.4
♦♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ TREATED 02%
♦♦ CONSTANT

TREATED **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 155,301
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.66	1.65	1.65	1.66	1.66	1.656
CO%	0.02	0.02	0.02	0.0	0.02	0.020
02%	18.80	18.60	18.80	18.50	18.80	18.70
HCppm	19.00	18.00	18.00	18.00	18.00	18.20
EXHST. TEMP. (F)	331	329	324	323	321	325.6
♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS UNIT NO. 115

EQUIPMENT: TRUCK
ENGINE: MACK MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 147,700
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.74	1.74	1.74	1.75	1.75	1.744
CO%	0.03	0.03	0.03	0.03	0.03	0.030
02%						19.08♦
HCppm	12.00	12.00	12.00	12.00	12.00	12.00
EXHST. TEMP. (F)	290	289	287	286	285	287.4
♦♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ TREATED 02%
♦♦ CONSTANT

TREATED **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 174,990
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.55	1.56	1.56	1.55	1.55	1.554
CO%	0.02	0.02	0.02	0.02	0.02	0.020
02%	19.10	18.90	19.10	19.10	19.20	19.08
HCppm	18.00	18.00	20.00	21.00	19.00	19.20
EXHST. TEMP. (F)	325	325	322	322	321	323.0
♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS — UNIT NO. 185

EQUIPMENT: TRUCK
ENGINE: MACK — MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE — **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 411,547
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.61	1.61	1.59	1.59	1.59	1.598
CO%	0.04	0.04	0.04	0.04	0.04	0.040
02%						19.20♦
HCppm	10.00	10.00	10.00	10.00	12.00	10.40
EXHST. TEMP. (F)	286	286	282	282	283	283.8
♦♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ TREATED 02%
♦♦ CONSTANT

TREATED — **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 436,100
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.49	1.44	1.50	1.49	1.50	1.484
CO%	0.02	0.02	0.02	0.02	0.02	0.020
02%	19.30	19.20	19.40	19.10	19.00	19.20
HCppm	19.00	19.00	19.00	19.00	20.00	19.20

EXHST. TEMP. (F)	321	319	318	317	315	318.0
♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ CONSTANT

EXHAUST GAS SUMMARY

COMPANY: CHARLEY BROTHERS — UNIT NO. 182

EQUIPMENT: TRUCK
ENGINE: MACK — MODEL: 300
FUEL: NO. 2 DIESEL

BASELINE — **DATE: APRIL 13, 1989**

ENGINE MILES (HRS.): 339,074
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 51 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.67	1.67	1.64	1.64	1.67	1.658
CO%	0.03	0.03	0.03	0.03	0.03	0.030
02%						18.54♦
HCppm	10.00	10.00	10.00	10.00	10.00	10.00
EXHST. TEMP. (F)	298	298	296	296	296	296.8
♦♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ TREATED 02%
♦♦ CONSTANT

TREATED — **DATE: JULY 20, 1989**

ENGINE MILES (HRS.): 364,295
ENGINE SPEED: 1500 RPM
AMB. TEMP.: 77 F
BAROMETRIC: -

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5	AVE.
CO2%	1.74	1.75	1.75	1.75	1.76	1.750
CO%	0.02	0.02	0.02	0.02	0.02	0.020
02%	18.50	18.30	18.80	18.60	18.50	18.54
HCppm	20.00	20.00	21.00	21.00	22.00	20.80
EXHST. TEMP. (F)	334	333	327	325	325	328.8
♦ EXHST. VOLUME(CFM)	425	425	425	425	425	425

♦ CONSTANT

Table 4

MOLECULAR WEIGHT OF EXHAUST GASES, ENGINE PERFORMANCE FACTORS AND FUEL ECONOMY IMPROVEMENTS AT 1500 RPM

Unit No. 127

Mwt1 28.9963
pf1 428,000
PF1 724,000

Mwt2 28.9844
pf2 451,000
PF2 795,000
PF2 765,000♦

% Improvement F.E. = [(795,000 - 724,000)/724,000](100)

% Improvement F.E. = + 9.81%

(♦ Corrected % Improvement F.E. = + 5.66%)

Unit No. 122

Mwt1 28.9792
pf1 435,000
PF1 728,000

Mwt2 28.9892
pf2 416,000
PF2 724,000
PF2 698,000♦

% Improvement F.E. = [(724,000 - 728,000)/728,000](100)

% Improvement F.E. = - .55%

(♦ Corrected % Improvement F.E. = - 4.12%)

Unit No. 181

Mwt1	29.0092	Mwt2	29.0102
pf1	360,000	pf2	363,000
PF1	629,000	PF2	666,000
		PF2	644,000♦

% Improvement F.E. = [(666,000 - 629,000)/629,000](100)

% Improvement F.E. = + 5.88%

(♦ Corrected % Improvement F.E. = + 2.38%)

Unit No. 114

Mwt1	29.0125	Mwt2	29.0149
pf1	366,000	pf2	365,000
PF1	636,000	PF2	674,000
		PF2	652,000♦

% Improvement F.E. = [(674,000 - 636,000)/636,000](100)

% Improvement F.E. = + 5.97%

(♦ Corrected Improvement F.E. = + 2.52%)

Unit No. 115

Mwt1	29.0432	Mwt2	29.0134
pf1	346,000	pf2	388,000
PF1	609,000	PF2	715,000
		PF2	691,000♦

% Improvement F.E. = [(691,000 - 609,000)/353,000](100)

% Improvement F.E. = + 17.41%

(♦ Corrected Improvement F.E. = + 13.46%)

Unit No. 185

Mwt1	29.0245	Mwt2	29.0070
pf1	375,000	pf2	406,000
PF1	656,000	PF2	743,000
		PF2	718,000♦

% Improvement F.E. = [(743,000 - 656,000)/656,000](100)

% Improvement F.E. = + 13.26%

(♦ Corrected Improvement F.E. = + 9.45%)

Unit No. 182

Mwt1	29.0077	Mwt2	29.0233
pf1	364,000	pf2	345,000
PF1	647,000	PF2	641,000
		PF2	619,000♦

% Improvement F.E. = [(641,000 - 647,000)/647,000](100)

% Improvement F.E. = - .93%

(♦ Corrected Improvement F.E. = - 4.33%)

Figure 7

SAMPLE CALCULATION FOR THE CARBON MASS BALANCE USING BASELINE AND TREATED DATA FROM UNIT NO. 127 AT 1800 RPM

Baseline:

Equation 1 Volume Fractions

VFCO2 = 1.614/100
= 0.01614

VFO2 = 19.12/100
= 0.1912

VFHC = 9.80/1,000,000
= 0.00000980

VFCO = 0.02/100
= 0.0002

Equation 2 Molecular Weight

Mwt1 =(0.00000980)(86)+(0.0002)(28)+(0.01614)(44)+(0.1912)(32)
+[(1-0.00000980-0.0002-0.1912-0.01614)(28)]

Mwt1 = 29.0238

Equation 3 Calculated Performance Factor

$$pf1 = \frac{2952.3 \times 29.0238}{86(0.00000980)+13.89(0.0002)+13.89(0.01614)}$$

pf1 = 376,000 (rounded to three significant places)

Equation 4 Performance Factor (adjusted for baseline exhaust mass)

$$PF1 = \frac{376{,}000 \times (278.0 + 460)}{630}$$

PF1 = 440,000 (rounded to three places)

Treated:

Equation 1 Volume Fractions

VFCO2 = 1.584/100
= 0.01584

VFO2 = 19.12/100
= 0.1912

VFHC = 15.0/1,000,000
= 0.0000150

VFCO = .02/100
= 0.0002

Equation 2 Molecular Weight

Mwt2 = (0.0000150)(86)+(0.0002)(28)+(0.01584)(44)+(0.1912)(32)
+[(1-0.0000150-0.0002-0.1912-0.01584)(28)]

Mwt2 = 29.0195

Equation 3 Calculated Performance Factor

$$pf2 = \frac{2952.3 \times 29.0195}{86(0.0000150)+13.89(0.0002)+13.89(0.01584)}$$

pf2 = 382,000

Equation 4 Performance Factor (adjusted for treated exhaust mass)

$$PF2 = \frac{382{,}000 \times (316.8 + 460)}{630}$$

PF2 = 471,000

Final Equation for Fuel Savings:

Equation 5 Percent Improvement, Engine Performance and Fuel Economy

% Improvement F.E. = [(471,000 - 440,000)/440,000](100)

= + 7.05%