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# EVALUATION OF FPC-1® FUEL PERFORMANCE CATALYST

# at

# LUSK

Draft

Report Prepared by

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Jim,
Call Kim or Craig with any Changes you would like on this Report.

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## 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 Unlimited, Lusk, 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 Mack 300 powered garbage trucks
1 x Cummins 315 powered garbage 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 Hewlett Packard Model 42S programmable calculator for the calculation of 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 Environment 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 temperature 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.

Three garbage trucks made up the final 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

### 1. Fuel Density

Fuel specific gravity (density) was higher during the treated fuel carbon balance test than the baseline fuel test, therefore, the fuel had greater energy content during the treated test. The correction factor shown on the computer printouts in the Appendices adjust the treated fuel density to that of the baseline.

### 2. The Effect of FPC-1 upon Smoke Density

Smoke density was determined using the Bacharach smoke spot method. The Bacharach True-Spot 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.

A reduction in smoke 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 are logical extensions of improved combustion created by FPC-1.

### 3. Volumetric Flowrate (Pitot Tube Readings)

The final calculation for determining the fuel flow rate or mass flow rate of the fuel into the engine takes into consideration the temperature and pressure velocity of all the gases in the exhaust. The exhaust gas temperature is recorded using a digital thermometer and thermocouple that is very accurate and easily fixed into place inside the exhaust stack. The pressure velocity readings are more difficult to measure because the pitot tube cannot be fixed inside the stack necessitating the use of a traversing method to locate the center velocity (the theoretical point of highest exhaust gas velocity). Therefore, the pitot tube readings are considered the least accurate and serve only as an indicator of engine speed or rpm.

The changes in the rate of fuel consumption shown are Table 1 are based upon carbon mass change in the exhaust alone, without correcting for exhaust volumetric flow rate (temperature and pressure). Since exhaust temperature and barometric pressure where virtually identical and engine speed was identical from test to test, exhaust pressure velocity is assumed to be constant from baseline to treated tests.

### 4. The Influence of New Engines on the Test Results

Laboratory and field tests alike indicate the change in fuel consumption created by the addition of FPC-1 is less profound in brand new or like new engines. It is a known fact that engine efficiency deteriorates as the engine ages. One of the causes of the efficiency loss is the accumulation of engine carbon deposits on injectors, valves, ring zone areas, and piston crowns. Along with the reaction to promote a smoother, more rapid combustion of the fuel hydrocarbons, the FPC-1 active ingredient also reactes with these combustion chamber deposits, gradually removing these from the system. The removal of the carbon deposits and the improved combustion of the injected fuel combine to create the total fuel consumption reduction available from FPC-1 fuel treatment. Engine studies have also shown that FPC-1 use from zero miles on an engine through it's entire useful life, prevents the formation of engine carbon, maintaining the engine's efficiency at a higher level than untreated fuel can.

The Luck study agrees with prior data. The two virtually new engines (Unit 36 and 37) realized the least improvement in fuel economy. Unit 36 was brand new with less than 2500 miles, while Unit 37 had accumulated only 16,000 miles at the time of the baseline test. These trucks realized a 3.09 and a 5.81% fuel consumption reduction, respectively, while the much older truck (Unit 10) having 132,000 miles realized a 7.32% fuel consumption reduction after FPC-1 fuel treatment. The 7.32% is more like the fuel savings seen in dozens of other tests on older engines.

## CONCLUSIONS

1) The fuel consumption change determined by the carbon balance method ranged from - 3.09 to - 7.32%. The fleet averaged a 5.41% reduction in fuel consumed after FPC-1 fuel treatment and engine preconditioning. The lower than average reduction in fuel consumption is in part due to the test being conducted on two virtually brand new engines (Units 37 and 36).

2) Smoke density was reduced approximately 50% with FPC-1 treated fuel.

# 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 (with the exception of shovel's #1 and #4) and checked peridocally to prevent any change in engine speed during the data collection period. # 2 diesel was used exclusively throughout the evaluation. Fuel specific gravity (density) and temperature were 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 $C0_2$, 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

| | | | | | |
|---|---|---|---|---|---|
| ***Company Name:*** | Lusk | ***Location*** | Princeton, WV | ***Date:*** | 4/20/94 |
| ***Test Portion:*** | Baseline | ***Stack Diam.*** | 6 Inches | | |
| ***Engine Type:*** | Mack 300 | ***Mile/Hrs*** | 2355 | | |
| ***Equipment Type:*** | Garbage Compactor | ***ID #:*** | 36 | ***Baro*** | 30.16 |
| ***Fuel Sp. Gravity(SG*** | 0.8400 | ***Temp:*** | 78 | ***Time:*** | 1605 |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
| 1700 | 364.4 | 1.1 | 0.02 | 8 | 2.14 | 16.8 | |
| 1700 | 366.2 | 1.1 | 0.02 | 8 | 2.16 | 16.8 | |
| 1700 | 367.2 | 1.1 | 0.02 | 6 | 2.1 | 16.8 | |
| 1700 | 366.4 | 1.1 | 0.02 | 6 | 2.08 | 16.8 | |
| 1700 | 367.2 | 1.1 | 0.02 | 6 | 2.08 | 16.8 | |
| 1700 | 368 | 1.1 | 0.02 | 6 | 2.09 | 16.7 | |
| 1700 | 366.4 | 1.1 | 0.02 | 8 | 2.14 | 16.8 | |
| 1700 | 365.4 | 1.1 | 0.02 | 6 | 2.15 | 16.8 | |
| 1700 | 367 | 1.1 | 0.02 | 7 | 2.15 | 16.8 | |
| 1700 | 365.8 | 1.1 | 0.02 | 6 | 2.15 | 16.8 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| **1700.000** | **366.400** | **1.100** | **.020** | **6.700** | **2.124** | **16.790** | Mean |
| **0** | **1.032795559** | **2.8098E-08** | **4.3903E-10** | **0.9486833** | **0.03238655** | **0.03162278** | Std Dev |

| **VFHC** | **VFCO** | **VFCO2** | **VFO2** | **Mtw1** | **pf1** |
|---|---|---|---|---|---|
| 6.70E-06 | 0.0002 | 0.02124 | 0.1679 | 29.0118286 | 287,038 |

| | | | | | |
|---|---|---|---|---|---|
| ***Company Name:*** | Lusk | ***Location:*** | Princeton, WV | ***Test Date:*** | 7/19/94 |
| ***Test Portion:*** | Treated | ***Stack Diam:*** | 6 Inches | | |
| ***Engine Type:*** | Mack 300 | ***Mile/Hrs:*** | 13375 | | |
| ***Equipment Type*** | Garbage Compactor | ***ID #:*** | 36 | ***Baro:*** | 30.20 |
| ***Fuel Sp. Gravity:*** | 0.848 | ***Temp:*** | 87 | | |
| ***SG Corr Factor:*** | 0.99 | | | ***Time:*** | 1630 |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
| 1700 | 362.8 | 0.95 | 0.02 | 5 | 2.06 | 16.9 | |
| 1700 | 364.2 | 0.95 | 0.02 | 5 | 2.06 | 16.9 | |
| 1700 | 365 | 0.95 | 0.02 | 5 | 2.06 | 16.9 | |
| 1700 | 365.8 | 0.95 | 0.02 | 5 | 2.06 | 16.8 | |
| 1700 | 360.2 | 0.95 | 0.02 | 6 | 2.06 | 16.9 | |
| 1700 | 359.6 | 0.95 | 0.02 | 6 | 2.06 | 16.9 | |
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| | | | | | | | |
| **1700.000** | **362.933** | **.950** | **.020** | **5.333** | **2.060** | **16.883** | Mean |
| **0** | **2.55708167** | **0** | **0** | **0.51639778** | **0** | **0.04082483** | Std Dev |

| **VFHC** | **VFCO** | **VFCO2** | **VFO2** | **Mtw2** | **pf2** |
|---|---|---|---|---|---|
| 5.33E-06 | 0.0002 | 0.0206 | 0.168833333 | 29.0052427 | 295,909 |

Performance factor adjusted for fuel density: 292,950

****% Change PF= 2.06**

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

| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location* | Princeton, WV | *Date:* | 4/20/94 |
| *Test Po tion:* | Baseline | *Stack Diam.* | 5 Inches | | |
| *Engine Type:* | Princeton | *Mile/Hrs* | 131846 | | |
| *Equipment Type:* | Cummins 315 | *ID #:* | 10 | *Baro* | 30.14 |
| *Fuel Sp. Gravity(SG* | 0.8400 | *Temp:* | 78 | | |
| | | | | *Time:* | 1800 |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
| 1900 | 402.4 | 1.3 | 0.02 | 7 | 2.45 | 16.4 | |
| 1900 | 403.4 | 1.3 | 0.02 | 7 | 2.43 | 16.4 | |
| 1900 | 403.4 | 1.3 | 0.02 | 7 | 2.41 | 16.4 | |
| 1900 | 404 | 1.3 | 0.02 | 6 | 2.42 | 16.3 | |
| 1900 | 404 | 1.3 | 0.02 | 8 | 2.39 | 16.4 | |
| 1900 | 404.2 | 1.3 | 0.02 | 7 | 2.38 | 16.3 | |
| 1900 | 403.6 | 1.3 | 0.02 | 7 | 2.42 | 16.3 | |
| 1900 | 402.4 | 1.3 | 0.02 | 8 | 2.4 | 16.4 | |
| 1900 | 402.2 | 1.3 | 0.02 | 8 | 2.41 | 16.4 | |
| 1900 | 402.4 | 1.3 | 0.02 | 8 | 2.4 | 16.4 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| **1900.000** | **403.200** | **1.300** | **.020** | **7.300** | **2.411** | **16.370** | Mean |
| **0** | **0.777460253** | **0** | **4.3903E-10** | **0.67494856** | **0.02024846** | **0.04830459** | Std Dev |

| VFHC | VFCO | VFCO2 | VFO2 | Mtw1 | pf1 |
|---|---|---|---|---|---|
| 7.30E-06 | 0.0002 | 0.02411 | 0.1637 | 29.0409834 | 253,425 |

| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location:* | Princeton, WV | *Test Date:* | 7/19/94 |
| *Test Portion:* | Treated | *Stack Diam:* | 5 Inches | | |
| *Engine Type:* | Princeton | *Mile/Hrs:* | 346989 | | |
| *Equipment Type* | Cummins 315 | *ID #:* | 10 | *Baro:* | 30.19 |
| *Fuel Sp. Gravity:* | 0.848 | *Temp:* | 87 | | |
| *SG Corr Factor:* | 0.99 | | | *Time:* | 1730 |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
| 1900 | 392.6 | 1.1 | 0.02 | 9 | 2.3 | 17 | |
| 1900 | 392.6 | 1.1 | 0.02 | 10 | 2.3 | 17 | |
| 1900 | 392 | 1.1 | 0.02 | 10 | 2.28 | 17 | |
| 1900 | 387.8 | 1.1 | 0.02 | 12 | 2.25 | 16.5 | |
| 1900 | 387.4 | 1.1 | 0.02 | 12 | 2.26 | 16.5 | |
| 1900 | 386.4 | 1.1 | 0.02 | 12 | 2.22 | 16.5 | |
| 1900 | 385 | 1.1 | 0.02 | 13 | 2.2 | 16.6 | |
| 1900 | 384 | 1.1 | 0.02 | 13 | 2.2 | 16.6 | |
| 1900 | 383.2 | 1.1 | 0.02 | 13 | 2.2 | 16.6 | |
| 1900 | 382.2 | 1.1 | 0.02 | 13 | 2.2 | 16.6 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| **1900.000** | **387.320** | **1.100** | **.020** | **11.700** | **2.241** | **16.690** | Mean |
| **0** | **3.92054418** | **2.8098E-08** | **4.3903E-10** | **1.49443412** | **0.04228212** | **0.21832697** | Std Dev |

| VFHC | VFCO | VFCO2 | VFO2 | Mtw2 | pf2 |
|---|---|---|---|---|---|
| 1.17E-05 | 0.0002 | 0.02241 | 0.1669 | 29.0268386 | 271,969 |

Performance factor adjusted for fuel density: 269,250

****% Change PF= 6.24**

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

| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location* | Princeton, WV | *Date:* | 4/20/94 |
| *Test Portion:* | Baseline | *Stack Diam.* | 5 Inches | | |
| *Engine Type:* | Mack 300 | *Mile/Hrs* | 15927 | | |
| *Equipment Type:* | Garbage Compactor | *ID #:* | 37 | *Baro* | 30.14 |
| *Fuel Sp. Gravity(SG* | 0.8400 | *Temp:* | 78 | *Time:* | |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
| 1700 | 310.2 | 0.75 | 0.02 | 8 | 1.83 | 17.4 | |
| 1700 | 310.6 | 0.9 | 0.02 | 6 | 1.84 | 17.4 | |
| 1700 | 310.6 | 0.9 | 0.02 | 6 | 1.82 | 17.4 | |
| 1700 | 310.6 | 0.9 | 0.02 | 6 | 1.83 | 17.4 | |
| 1700 | 310.4 | 0.9 | 0.02 | 5 | 1.82 | 17.4 | |
| 1700 | 310.6 | 0.9 | 0.02 | 5 | 1.84 | 17.4 | |
| 1700 | 314.2 | 0.9 | 0.02 | 6 | 1.83 | 17.2 | |
| 1700 | 315.2 | 0.9 | 0.02 | 7 | 1.84 | 17.2 | |
| 1700 | 316.4 | 0.9 | 0.02 | 6 | 1.83 | 17.3 | |
| 1700 | 316.4 | 0.9 | 0.02 | 6 | 1.83 | 17.3 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| **1700.000** | **312.520** | **.885** | **.020** | **6.100** | **1.831** | **17.340** | Mean |
| **0** | **2.681956168** | **0.04743416** | **4.3903E-10** | **0.87559504** | **0.00737865** | **0.0843274** | Std Dev |

| **VFHC** | **VFCO** | **VFCO2** | **VFO2** | **Mtw1** | **pf1** |
|---|---|---|---|---|---|
| 6.10E-06 | 0.0002 | 0.01831 | 0.1734 | 28.9869138 | 332,153 |

| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location:* | Princeton, WV | *Test Date:* | 7/19/94 |
| *Test Portion:* | Treated | *Stack Diam:* | 5 Inches | | |
| *Engine Type:* | Mack 300 | *Mile/Hrs:* | 35264 | | |
| *Equipment Type* | Garbage Compactor | *ID #:* | 37 | *Baro:* | 30.18 |
| *Fuel Sp. Gravity:* | 0.848 | *Temp:* | 87 | | |
| *SG Corr Factor:* | 0.99 | | | *Time:* | |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
| 1700 | 301.4 | 0.75 | 0.02 | 5 | 1.72 | 17.4 | |
| 1700 | 301.8 | 0.75 | 0.02 | 5 | 1.72 | 17.4 | |
| 1700 | 301.8 | 0.75 | 0.02 | 6 | 1.72 | 17.3 | |
| 1700 | 302.8 | 0.75 | 0.02 | 6 | 1.73 | 17.4 | |
| 1700 | 302.8 | 0.75 | 0.02 | 6 | 1.73 | 17.4 | |
| 1700 | 303.2 | 0.75 | 0.02 | 6 | 1.74 | 17.4 | |
| 1700 | 303.4 | 0.75 | 0.02 | 6 | 1.74 | 17.5 | |
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| | | | | | | | |
| **1700.000** | **302.457** | **.750** | **.020** | **5.714** | **1.729** | **17.400** | Mean |
| **0** | **0.780720058** | **0** | **0** | **0.48795004** | **0.00899735** | **0.05773503** | Std Dev |

| **VFHC** | **VFCO** | **VFCO2** | **VFO2** | **Mtw2** | **pf2** |
|---|---|---|---|---|---|
| 5.71E-06 | 0.0002 | 0.01728571 | 0.174 | 28.9729029 | 351,446 |

Performance factor adjusted for fuel density: 347,931

****% Change PF= 4.75**

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

**Table 1:**
Summary of Carbon Balance Fuel Consumption Changes

| Unit | Engine | THROTTLE | % Change Fuel Consumption |
|---|---|---|---|
| 36 | Mack 300 | 1700 | - 3.09 |
| 37 | Mack 300 | 1700 | - 5.81 |
| 10 | Cummins 315 | 1900 | - 7.32 |
| **Average:** | | | **- 5.41** |

**Table 2:**
Comparison of Smoke Spot Numbers

| Unit No. | Base SS# | Treated SS# | % Change |
|---|---|---|---|
| 36 | 6.0 | 3.0 | 50 |
| 37 | 8.0 | 3.0 | 62 |
| 10 | 9.5 | 6.0 | 37 |
| **Average:** | | | **49.7** |

## 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 $H_20$
$P_B$ = Barometric pressure in inches of mercury
Te = Exhaust temperature $^{O}F$

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

**EQUATIONS:**

$$Mwt = (VFHC)(86)+(VFCO)(28)+(VFCO_2)(44)+(VFO_2)(32)+[(1-VFHC-VFCO-VFCO_2-VFO_2)(28)]$$

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

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

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

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)**

$$CFM = \frac{(d/2)^2\pi}{144} \bullet 1096.2\sqrt{\frac{Pv}{1.325\{P_B/(Te + 460)\}}}$$

| | |
|---|---|
| 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 $^OF$ |

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

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)**

$$CFM = \frac{(d/2)^2\pi}{144} \bullet 1096.2\sqrt{\frac{Pv}{1.325\ \{P_B/(Te + 460)\}}}$$

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 $^OF$

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

$$CFM = 2320.51$$

**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:)**

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

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

= +7.65

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

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Item: 4    Code: CWV

1600 ~~2PM~~ Tue 19 July    WEST VIRGINIA this hour    TODAY'S DATA

| TOWN | WEATHER | TEMP | WIND | FLSLK | VIS | HUM | BRMTR | HI | LOW | PCPN |
|---|---|---|---|---|---|---|---|---|---|---|
| Wheeling | ptly cldy | 86 | W 9 | 100 | 8 | 55% | 30.13s | 86 | 64 | |
| Morgantown | haze | 88 | SW 6 | 100 | 5 | 48% | 30.13f | 88 | 64 | |
| Clarksburg | haze | 87 | W 8 | 99 | 5 | 50% | 30.12f | 87 | 63 | |
| Parkersburg | haze | 88 | S 6 | 100 | 6 | 48% | 30.12f | 88 | 64 | |
| Elkins | mstly cldy | 85 | NW 7 | 99 | 7 | 57% | 30.19f | 87 | 61 | |
| Martinsburg | ptly cldy | 90 | E 10 | 103 | 8 | 47% | 30.10s | 90 | 68 | |
| Huntington | haze | 92 | NE 6 | 105 | 6 | 44% | 30.07f | 92 | 67 | |
| Charleston | haze | 88 | SE 5 | 102 | 5 | 52% | 30.09f | 88 | 66 | |
| Beckly | thunder | 77 | NE 11G21 | 89 | 7 | 69% | 30.20s | 83 | 64 | |
| Lewisburg | lgt rain | 78 | SE 11G23 | 100 | 7 | 97% | 30.19s | 83 | 61 | |
| White SulfSpg | ........... | | | | | | | | | |
| Bluefield | ptly cldy | 87 | SE 9 | 96 | 10 | 43% | 30.20f | 88 | 65 | |

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Final

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Item: 4    Code: CWV

1700 ~~3PM~~ Tue 19 July    WEST VIRGINIA this hour    TODAY'S DATA

| TOWN | WEATHER | TEMP | WIND | FLSLK | VIS | HUM | BRMTR | HI | LOW | PCPN |
|---|---|---|---|---|---|---|---|---|---|---|
| Wheeling | ptly cldy | 86 | W 7 | 101 | 8 | 57% | 30.12f | 86 | 64 | |
| Morgantown | haze | 87 | S 7 | 98 | 5 | 46% | 30.12f | 88 | 64 | |
| Clarksburg | haze | 88 | NW 6 | 100 | 5 | 47% | 30.11f | 88 | 63 | |
| Parkersburg | haze | 87 | W 6 | 99 | 6 | 50% | 30.10f | 88 | 64 | |
| Elkins | mstly cldy | 81 | NW 5 | 95 | 7 | 65% | 30.19s | 87 | 61 | |
| Martinsburg | haze | 90 | SE 9 | 102 | 6 | 45% | 30.09f | 90 | 68 | |
| Huntington | haze | 91 | NE 6 | 103 | 6 | 44% | 30.06f | 92 | 67 | |
| Charleston | haze | 89 | NE 5 | 103 | 5 | 50% | 30.08f | 89 | 66 | |
| Beckly | thunder | 76 | SE 9 | 90 | 7 | 76% | 30.20s | 83 | 64 | 0.17 |
| Lewisburg | mstly cldy | 74 | CALM | 88 | 7 | 82% | 30.19s | 83 | 61 | |
| White SulfSpg | ........ | | | | | | | | | |
| Bluefield | ptly cldy | 87 | E 7 | 96 | 10 | 42% | 30.19f | 88 | 65 | |

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Final

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Item: 2 Code: CWV

~~11AM~~ 1 Wed 20 April WEST VIRGINIA this hour TODAY'S DATA

| TOWN | WEATHER | TEMP | WIND | FLSLK | VIS | HUM | BRMTR | HI | LOW | PCPN |
|---|---|---|---|---|---|---|---|---|---|---|
| Wheeling | mstly clr | 57 | NW 9 | 50 | 20 | 39% | 30.20f | 57 | 44 | |
| Morgantown | mstly clr | 59 | W 14 | 49 | 25 | 31% | 30.17f | 59 | 43 | |
| Clarksburg | clear | 64 | W 11 | 57 | 20 | 19% | 30.16f | 64 | 44 | |
| Parkersburg | clear | 62 | N 9 | 56 | 25 | 22% | 30.22f | 62 | 42 | |
| Elkins | mstly clr | 63 | NW 17 | 52 | 15 | 26% | 30.19f | 63 | 35 | |
| Martinsburg | no report | 66 | NW 14G23 | 58 | | 24% | 30.09f | 66 | 54 | |
| Huntington | clear | 67 | N 8 | 63 | 15 | 31% | 30.20f | 67 | 50 | |
| Charleston | clear | 67 | W 9 | 62 | 20 | 24% | 30.19f | 67 | 50 | |
| Beckly | clear | 65 | NW 14 | 56 | 20 | 22% | 30.21s | 65 | 50 | |
| Lewisburg | clear | 65 | NW 11G23 | 58 | 20 | 37% | 30.15f | 65 | 48 | |
| White SulfSpg | ............ | | | | | | | | | |
| Bluefield | clear | 67 | NW 11G23 | 61 | 20 | 16% | 30.18f | 67 | 54 | |

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Item: 2 Code: CWV

2PM Wed 20 April — WEST VIRGINIA this hour — TODAY'S DATA

| TOWN | WEATHER | TEMP | WIND | FLSLK | VIS | HUM | BRMTR | HI | LOW | PCPN |
|---|---|---|---|---|---|---|---|---|---|---|
| Wheeling | mstly clr | 61 | NW 14 | 51 | 20 | 34% | 30.16f | 61 | 44 | |
| Morgantown | ptly cldy | 63 | N 7 | 59 | 25 | 21% | 30.13f | 63 | 43 | |
| Clarksburg | ................................................................ | | | | | | | | | |
| Parkersburg | clear | 66 | NW 8 | 62 | 25 | 22% | 30.17f | 66 | 42 | |
| Elkins | ptly cldy | 65 | NW 9 | 60 | 15 | 17% | 30.14f | 65 | 35 | |
| Martinsburg | ptly cldy | 68 | NW 14 | 60 | 25 | 19% | 30.05f | 69 | 54 | |
| Huntington | clear | 71 | E 6 | 69 | 15 | 21% | 30.14f | 71 | 50 | |
| Charleston | clear | 69 | NW 6 | 67 | 20 | 18% | 30.14f | 69 | 50 | |
| Beckly | clear | 68 | NW 14 | 60 | 20 | 19% | 30.17f | 68 | 50 | |
| Lewisburg | clear | 69 | W 11 | 63 | 20 | 24% | 30.12f | 69 | 48 | |
| White SulfSpg | ................................................................ | | | | | | | | | |
| Bluefield | clear | 71 | NW 11G23 | 66 | 20 | 17% | 30.16f | 71 | 53 | |

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# <u>Interim Report</u>
# Lusk Field Trial of FPC-1 Fuel Performance Catalyst

**Prepared by UHI Corporation**
**Provo, Utah**

**May 3, 1994**

# I. Introduction

FPC-1 Fuel Performance Catalyst is a burn rate modifier 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 positive impact upon the products of incomplete combustion, primarily soot (smoke) and carbon monoxide.

The intent of the current trial at Lusk is to determine the degree of fuel consumption, smoke and carbon monoxide reduction resulting from the addition of the FPC-1 catalyst to the # 2 diesel fuelling a select fleet of haul trucks. 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 (CO2, CO, HC) found in the exhaust, rather than directly measuring fuel flow into the engine.

This report summarizes the baseline fuel emissions data and computes the engine performance factors (mass flow rates) for the same.

# II. Discussion of Carbon Mass Balance Method

The data collected during the baseline fuel carbon balance test are summarized on the attached computer printouts. This data provides 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, and total exhaust mass yielding a corrected engine performance factor (PF). The baseline PFs are tabulated on Table 1 below. The baseline PFs will be compared to FPC-1 treated fuel PFs and a percent change in mass carbon flow rate (fuel consumption) computed. This percent change equates to the fuel consumption change created by the addition of FPC-1.

Also, the treated fuel PF must be corrected for any change in fuel density (measured as specific gravity), and therefore, energy content. The baseline fuel density is used as the reference. No correction factor is shown in the attached printouts. These will be tabulated and shown in the final report.

The CMB procedure is conducted while the engine is operated under steady-state conditions at a high idle. No load is placed on the engine. Consequently, the engine is tested while operating under conditions conducive to high efficiency and low emissions of the products of incomplete combustion. The CMB results, therefore, represent minimum improvements, and FPC-1 created engine efficiency should be higher under high load/transient operation.

## Table 1. Comparison of Baseline PFs

| Unit No. | Engine Type | Baseline PF |
|---|---|---|
| 4 | Mack 300 | 243,980 |
| 36 | Mack 300 | 231,187 |
| 10 | Cummins 315 | 276,237 |
| 37 | Mack 300 | 415,110 |

## III. Discussion of Bacharach Smoke Spot Method

Smoke density was determined using the Bacharach Smoke Spot method. The Bacharach method draws a constant volume of exhaust gas through a filter medium. The particulate in the exhaust gas sample collects on the surface of the filter medium. The surface is darkened by the particulate according to the density of the particulate in the exhaust sample. The greater the particulate density, the darker the color. The Bacharach smoke scale ranges from 0 to 9, with 0 being a white, particulate free filter, and 9 being a completely black filter.

The smoke spot (density) numbers for each engine tested are shown on Table 2 below. The FPC-1 treated smoke spot numbers will be compared to the baseline smoke numbers.

## Table 2: Smoke Numbers

| Unit No. | Smoke No. |
|---|---|
| 4 | 4.0 |
| 36 | 6.0 |
| 10 | 9.0 |
| 37 | 8.0 |
| **Fleet Average:** | **6.75** |

## IV. Summary

The baseline CMB and Bacharach Smoke Spot procedures have been completed at Luck. The Bacharach Smoke Spot test has also been done. Carbon monoxide emissions are part of the CMB, and therefore, are also available for comparison to the treated fuel concentrations.

The Lusk's fuel system is treated with FPC-1. The engine preconditioning period will be completed after approximately 500 hours of engine operation.

| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location* | Princeton, WV | *Date:* | 4/20/94 |
| *Test Portion:* | Baseline | *Stack Diam.* | 6 Inches | | |
| *Engine Type:* | Mack 300 | *Mile/Hrs* | 142907 | | |
| *Equipment Type:* | Garbage Compactor | *ID #:* | 4 | *Baro* | 30.18 |
| *Fuel Sp. Gravity(SG* | 0.8400 | *Temp:* | 78 | *Time:* | 1530 |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
| 1725 | 366.4 | 0.8 | 0.02 | 10 | 2.37 | 16.4 | |
| 1725 | 368.8 | 0.8 | 0.02 | 10 | 2.36 | 16.4 | |
| 1725 | 370.4 | 0.8 | 0.02 | 10 | 2.4 | 16.4 | |
| 1725 | 371.6 | 0.8 | 0.02 | 10 | 2.38 | 16.4 | |
| 1725 | 372.2 | 0.8 | 0.02 | 10 | 2.4 | 16.4 | |
| 1725 | 374 | 0.8 | 0.02 | 10 | 2.34 | 16.4 | |
| 1725 | 374.4 | 0.8 | 0.02 | 10 | 2.32 | 16.4 | |
| 1725 | 373 | 0.8 | 0.02 | 10 | 2.36 | 16.4 | |
| 1725 | 373.2 | 0.8 | 0.02 | 10 | 2.39 | 16.4 | |
| 1725 | 372.8 | 0.3 | 0.02 | 10 | 2.39 | 16.4 | |
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| | | | | | | | |
| **1725.000** | **371.680** | **.800** | **.020** | **10.000** | **2.371** | **16.400** | Mean |
| **0** | **2.498355014** | **1.9868E-08** | **4.3903E-10** | **0** | **0.02643651** | **0** | Std Dev |

| VFHC | VFCO | VFCO2 | VFO2 | Mtw1 | pf1 | PF1 |
|---|---|---|---|---|---|---|
| 1.00E-05 | 0.0002 | 0.02371 | 0.164 | 29.03594 | 257,426 | 243,980 |

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| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location:* | Princeton, WV | *Test Date:* | |
| *Test Portion:* | Treated | *Stack Diam:* | 6 Inches | | |
| *Engine Type:* | Mack 300 | *Mile/Hrs:* | | | |
| *Equipment Type* | Garbage Compactor | *ID #:* | 4 | *Baro:* | |
| *Fuel Sp. Gravity:* | | *Temp:* | | | |
| *SG Corr Factor:* | | | | *Time:* | |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
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| **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | Std Dev |

| VFHC | VFCO | VFCO2 | VFO2 | Mtw2 | pf2 | PF2 |
|---|---|---|---|---|---|---|
| #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |

Performance factor adjusted for fuel density: #DIV/0!

****% Change PF= ##### %**

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

| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location* | Princeton, WV | *Date:* | 4/20/94 |
| *Test Portion:* | Baseline | *Stack Diam.* | 6 Inches | | |
| *Engine Type:* | Mack 300 | *Mile/Hrs* | 2355 | | |
| *Equipment Type:* | Garbage Compactor | *ID #:* | 36 | *Baro* | 30.16 |
| *Fuel Sp. Gravity(SG* | 0.8400 | *Temp:* | 78 | *Time:* | 1605 |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
| 1700 | 364.4 | 1.1 | 0.02 | 8 | 2.14 | 16.8 | |
| 1700 | 366.2 | 1.1 | 0.02 | 8 | 2.16 | 16.8 | |
| 1700 | 367.2 | 1.1 | 0.02 | 6 | 2.1 | 16.8 | |
| 1700 | 366.4 | 1.1 | 0.02 | 6 | 2.08 | 16.8 | |
| 1700 | 367.2 | 1.1 | 0.02 | 6 | 2.08 | 16.8 | |
| 1700 | 368 | 1.1 | 0.02 | 6 | 2.09 | 16.7 | |
| 1700 | 366.4 | 1.1 | 0.02 | 8 | 2.14 | 16.8 | |
| 1700 | 365.4 | 1.1 | 0.02 | 6 | 2.15 | 16.8 | |
| 1700 | 367 | 1.1 | 0.02 | 7 | 2.15 | 16.8 | |
| 1700 | 365.8 | 1.1 | 0.02 | 6 | 2.15 | 16.8 | |
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| **1700.000** | **366.400** | **1.100** | **.020** | **6.700** | **2.124** | **16.790** | Mean |
| **0** | **1.032795559** | **2.8098E-08** | **4.3903E-10** | **0.9486833** | **0.03238655** | **0.03162278** | Std Dev |

| VFHC | VFCO | VFCO2 | VFO2 | Mtw1 | pf1 | PF1 |
|---|---|---|---|---|---|---|
| 6.70E-06 | 0.0002 | 0.02124 | 0.1679 | 29.0118286 | 287,038 | 231,187 |

| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location:* | Princeton, WV | *Test Date:* | |
| *Test Portion:* | Treated | *Stack Diam:* | 6 Inches | | |
| *Engine Type:* | Mack 300 | *Mile/Hrs:* | | | |
| *Equipment Type* | Garbage Compactor | *ID #:* | 36 | *Baro:* | |
| *Fuel Sp. Gravity:* <br> *SG Corr Factor:* | | *Temp:* | | *Time:* | |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
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| VFHC | VFCO | VFCO2 | VFO2 | Mtw2 | pf2 | PF2 |
|---|---|---|---|---|---|---|
| #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |

Performance factor adjusted for fuel density: #DIV/0!

****% Change PF= #####** %

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

| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location* | Princeton, WV | *Date:* | 4/20/94 |
| *Test Portion:* | Baseline | *Stack Diam.* | 5 Inches | | |
| *Engine Type:* | Princeton | *Mile/Hrs* | 131846 | | |
| *Equipment Type:* | Cummins 315 | *ID #:* | 10 | *Baro* | 30.14 |
| *Fuel Sp. Gravity(SG* | 0.8400 | *Temp:* | 78 | | |
| | | | | *Time:* | 1800 |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
| 1900 | 402.4 | 1.3 | 0.02 | 7 | 2.45 | 16.4 | |
| 1900 | 403.4 | 1.3 | 0.02 | 7 | 2.43 | 16.4 | |
| 1900 | 403.4 | 1.3 | 0.02 | 7 | 2.41 | 16.4 | |
| 1900 | 404 | 1.3 | 0.02 | 6 | 2.42 | 16.3 | |
| 1900 | 404 | 1.3 | 0.02 | 8 | 2.39 | 16.4 | |
| 1900 | 404.2 | 1.3 | 0.02 | 7 | 2.38 | 16.3 | |
| 1900 | 403.6 | 1.3 | 0.02 | 7 | 2.42 | 16.3 | |
| 1900 | 402.4 | 1.3 | 0.02 | 8 | 2.4 | 16.4 | |
| 1900 | 402.2 | 1.3 | 0.02 | 8 | 2.41 | 16.4 | |
| 1900 | 402.4 | 1.3 | 0.02 | 8 | 2.4 | 16.4 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| **1900.000** | **403.200** | **1.300** | **.020** | **7.300** | **2.411** | **16.370** | Mean |
| **0** | **0.777460253** | **0** | **4.3903E-10** | **0.67494856** | **0.02024846** | **0.04830459** | Std Dev |

| VFHC | VFCO | VFCO2 | VFO2 | Mtw1 | pf1 | PF1 |
|---|---|---|---|---|---|---|
| 7.30E-06 | 0.0002 | 0.02411 | 0.1637 | 29.0409834 | 253,425 | 276,234 |

| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location:* | Princeton, WV | *Test Date:* | |
| *Test Portion:* | Treated | *Stack Diam:* | 5 Inches | | |
| *Engine Type:* | Princeton | *Mile/Hrs:* | | | |
| *Equipment Type* | Cummins 315 | *ID #:* | 10 | *Baro:* | |
| *Fuel Sp. Gravity:*<br>*SG Corr Factor:* | | *Temp:* | | *Time:* | |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
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| VFHC | VFCO | VFCO2 | VFO2 | Mtw2 | pf2 | PF2 |
|---|---|---|---|---|---|---|
| #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |

Performance factor adjusted for fuel density: #DIV/0!

****% Change PF= #####** %

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

| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location* | Princeton, WV | *Date:* | 4/20/94 |
| *Test Portion:* | Baseline | *Stack Diam.* | 5 Inches | | |
| *Engine Type:* | Mack 300 | *Mile/Hrs* | 15927 | | |
| *Equipment Type:* | Garbage Compactor | *ID #:* | 37 | *Baro* | 30.14 |
| *Fuel Sp. Gravity(SG* | 0.8400 | *Temp:* | 78 | *Time:* | |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
| 1700 | 310.2 | 0.75 | 0.02 | 8 | 1.83 | 17.4 | |
| 1700 | 310.6 | 0.9 | 0.02 | 6 | 1.84 | 17.4 | |
| 1700 | 310.6 | 0.9 | 0.02 | 6 | 1.82 | 17.4 | |
| 1700 | 310.6 | 0.9 | 0.02 | 6 | 1.83 | 17.4 | |
| 1700 | 310.4 | 0.9 | 0.02 | 5 | 1.82 | 17.4 | |
| 1700 | 310.6 | 0.9 | 0.02 | 5 | 1.84 | 17.4 | |
| 1700 | 314.2 | 0.9 | 0.02 | 6 | 1.83 | 17.2 | |
| 1700 | 315.2 | 0.9 | 0.02 | 7 | 1.84 | 17.2 | |
| 1700 | 316.4 | 0.9 | 0.02 | 6 | 1.83 | 17.3 | |
| 1700 | 316.4 | 0.9 | 0.02 | 6 | 1.83 | 17.3 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| **1700.000** | **312.520** | **.885** | **.020** | **6.100** | **1.831** | **17.340** | Mean |
| **0** | **2.681956168** | **0.04743416** | **4.3903E-10** | **0.87559504** | **0.00737865** | **0.0843274** | Std Dev |

| VFHC | VFCO | VFCO2 | VFO2 | Mtw1 | pf1 | PF1 |
|---|---|---|---|---|---|---|
| 6.10E-06 | 0.0002 | 0.01831 | 0.1734 | 28.9869138 | 332,153 | 415,110 |

| | | | | | |
|---|---|---|---|---|---|
| *Company Name:* | Lusk | *Location:* | Princeton, WV | *Test Date:* | |
| *Test Portion:* | Treated | *Stack Diam:* | 5 Inches | | |
| *Engine Type:* | Mack 300 | *Mile/Hrs:* | | | |
| *Equipment Type* | Garbage Compactor | *ID #:* | 37 | *Baro:* | |
| *Fuel Sp. Gravity:* <br> *SG Corr Factor:* | | *Temp:* | | *Time:* | |

| RPM | Exh Temp | Pv Inch | CO | HC | CO2 | O2 | |
|---|---|---|---|---|---|---|---|
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| **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | Mean |
| **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | Std Dev |

| VFHC | VFCO | VFCO2 | VFO2 | Mtw2 | pf2 | PF2 |
|---|---|---|---|---|---|---|
| #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |

Performance factor adjusted for fuel density: #DIV/0!

****% Change PF= ##### %**

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

# Carbon Mass Balance Field Data Form

Company: LUSK Location: PRINCETON Test Date: 4/20/94
Test Portion: Baseline: XXX Treated: ______ Exhaust Stack Diameter: 6 Inches

Engine Make/Model: MACK 300 4 valve Miles/~~Hours~~: 202355 I.D.#: 36
Type of Equipment: GARBAGE COMPACTOR

Fuel Specfic Gravity: .84 @: 78° (°F)

Barometric Pressure: 30.16 inches of Mercury Start Time: 4:05 PM

| RPM | Exhaust Temp °F | P Inches of $H_2O$ | % CO | HC ppm | % $CO_2$ | % $O_2$ | $NO_x$ |
|---|---|---|---|---|---|---|---|
| 1700 | 364.4 | 1.1 | .02 | 8 | 2.14 | 16.8 | |
| | 366.2 | 1.1 | .02 | 8 | 2.16 | 16.8 | |
| | 367.0 | 1.1 | CALIB .02 | 6 | 2.10 | 16.8 | |
| | 366.4 | 1.1 | .02 | 6 | 2.08 | 16.8 | |
| | 367.2 | 1.1 | .02 | 6 | 2.08 | 16.8 | |
| | 368.0 | 1.1 | .02 | 6 | 2.09 | 16.7 | |
| | 366.4 | 1.1 | CALIB .02 | 8 | 2.14 | 16.8 | |
| | 365.4 | 1.1 | .02 | 6 | 2.15 | 16.8 | |
| | 367.0 | 1.1 | .02 | 7 | 2.15 | 16.8 | |
| | 365.8 | 1.1 | .02 | 6 | 2.15 | 16.8 | |

New Truck

SMOKE SPOT = 6

LUSK #36

Names of Customer Personnel Participating in Test:

Paul

Signature of Technicians:

Craig Kim

# Carbon Mass Balance Field Data Form

Company: LUSK Location: PRINCETON Test Date: 4/20/94
Test Portion: Baseline: XXX Treated: ______ Exhaust Stack Diameter: 5 Inches
Engine Make/Model: MACK 300 4VALVE Miles/Hours: 15927 140 hr I.D.#: 37
Type of Equipment: ______

Fuel Specfic Gravity: .840 @: 78° (°F)

Barometric Pressure: 30.14 inches of Mercury Start Time: ______

| RPM | Exhaust Temp °F | P Inches of $H_2O$ | % CO | HC ppm | % $CO_2$ | % $O_2$ | $NO_x$ |
|---|---|---|---|---|---|---|---|
| 1700 | 310.2 | 0.75 | .02 | 8 | 1.83 | 17.4 | |
| | 310.6 | 0.90 | .02 | 6 | 1.84 | 17.4 | |
| | 310.6 | 0.90 | CALIB .02 | 6 | 1.82 | 17.4 | |
| | 310.6 | 0.90 | .02 | 6 | 1.83 | 17.4 | |
| | 310.4 | 0.90 | .02 | 5 | 1.82 | 17.4 | |
| | 310.6 | 0.90 | .02 | 5 | 1.84 | 17.4 | |
| | 314.2 | 0.90 | CALIB .02 | 6 | 1.83 | 17.2 | |
| | 315.2 | 0.90 | .02 | 7 | 1.84 | 17.2 | |
| | 316.4 | 0.90 | .02 | 6 | 1.83 | 17.3 | |
| | 316.4 | 0.90 | .02 | 6 | 1.83 | 17.3 | |

Water 180°

Oil 60#

✓

37 fuel

Names of Customer Personnel Participating in Test:

Roger ______ ______

Smoke Spot Test = 8

Signature of Technicians:

Craig ______ Kim ______

# Carbon Mass Balance Field Data Form

Company: Lusk Location: PRINCETON Test Date: 4/20/94
Test Portion: Baseline: ✓ Treated: Exhaust Stack Diameter: 5 Inches

Engine Make/Model: CUMMINS 315 PAYSTAR 5000 Miles/~~Hours~~: 131,846 I.D.#: 10
Type of Equipment: INTERNATIONAL

Fuel Specfic Gravity: .84 @: 78 (°F)

Barometric Pressure: 30.14 inches of Mercury Start Time: 1800

| RPM | Exhaust Temp °F | P Inches of $H_2O$ | % CO | HC ppm | % $CO_2$ | % $O_2$ | $NO_x$ |
|---|---|---|---|---|---|---|---|
| 1900 | 402.4 | 1.3 | .02 | 7 | 2.45 | 16.4 | |
| | 403.4 | 1.3 | .02 | 7 | 2.43 | 16.4 | |
| | 403.4 | 1.3 | CALIB .02 | 7 | 2.41 | 16.4 | |
| | 404.0 | 1.3 | .02 | 6 | 2.42 | 16.3 | |
| | 404.0 | 1.3 | .02 | 8 | 2.39 | 16.4 | |
| | 404.2 | 1.3 | .02 | 7 | 2.38 | 16.3 | |
| | 403.6 | 1.3 | .02 | 7 | 2.42 | 16.3 | |
| | 402.4 | 1.3 | CALIB .02 | 8 | 2.40 | 16.4 | |
| | 402.2 | 1.3 | .02 | 8 | 2.41 | 16.4 | |
| | 402.4 | 1.3 | .02 | 8 | 2.40 | 16.4 | |

H2O Temp 165°F

Oil Press 40 PSI

LUSK 10

Names of Customer Personnel Participating in Test:

Paul

SMOKE TEST = 9+

Signature of Technicians:

[signature] [signature]

Company: LUSK Location: PRINCETON Test Date: 4/29/94
Test Portion: Baseline: XXX Treated: ______ Exhaust Stack Diameter: 6 Inches

Engine Make/Model: MACK 300 2 VALVE Miles/Hours: 142907 I.D.#: 4 142907
Type of Equipment: GARBAGE COMPACTOR

Fuel Specfic Gravity: .840 @: 78 (°F)

Barometric Pressure: 30.18 inches of Mercury Start Time: 3:30 PM

| RPM | Exhaust Temp °F | P Inches of $H_2O$ | % CO | HC ppm | % $CO_2$ | % $O_2$ | $NO_x$ |
|---|---|---|---|---|---|---|---|
| 1725 | 366.4 | 0.8 | .02 | 10 | 2.37 | 16.4 | |
| | 368.8 | .8 | .02 | 10 | 2.36 | 16.4 | |
| | 370.4 | .8 | .02 | 10 | 2.40 | 16.4 | |
| | 371.6 | .8 | .02 | 10 | 2.38 | 16.4 | |
| | 372.2 | .8 | .02 | 10 | 2.40 | 16.4 | |
| | 374.0 | .8 | CALIB .02 | 10 | 2.34 | 16.4 | |
| | 374.4 | .8 | .02 | 10 | 2.32 | 16.4 | |
| | 373.0 | .8 | CALIB .02 | 10 | 2.36 | 16.4 | |
| | 373.2 | .8 | .02 | 10 | 2.39 | 16.4 | |
| | 372.8 | .8 | .02 | 10 | 2.39 | 16.4 | |

1725

Water 180°

oil press 25#

LUSK #4

Smoke Test = 9

**Names of Customer Personnel Participating in Test:**

Paul

**Signature of Technicians:**

Craig Kim

# Carbon Mass Balance Field Data Form

Company: LUSK Location: PRINCETON Test Date: 7/19
Test Portion: Baseline: ______ Treated: ✓ Exhaust Stack Diameter: __Inches

Engine Make/Model: MACK 300 4VALVE Miles/Hours: 35264 1591 I.D.#: 37
Type of Equipment: ______

Fuel Specfic Gravity: .848 @: ______ (°F)

Barometric Pressure: 30.18 inches of Mercury Start Time: ______

| RPM | Exhaust Temp °F | P Inches of $H_2O$ | % CO | HC ppm | % $CO_2$ | % $O_2$ | $NO_x$ |
|---|---|---|---|---|---|---|---|
| 1700 | 301.4 | .75 | .02 | 5 | 1.72 | 17.4 | |
| | 301.8 | .75 | .02 | 5 | 1.72 | 17.4 | |
| | 301.8 | .75 | .02 | 6 | 1.72 | 17.3 | |
| | AUTO CAL | | | | | | |
| | 302.8 | .75 | .02 | 6 | 1.73 | 17.4 | |
| | 302.8 | .75 | .02 | 6 | 1.73 | 17.4 | |
| | 303.2 | .75 | .02 | 6 | 1.74 | 17.4 | |
| | 303.4 | .75 | .02 | 6 | 1.74 | 17.5 | |
| | | | | | | | |
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**Names of Customer Personnel Participating in Test:**

Smoke = 3

**Signature of Technicians:**

#37
7/19

# Carbon Mass Balance Field Data Form

Company: LUSK Location: PRINCETON Test Date: 7/19/94
Test Portion: Baseline: ______ Treated: ✓ Exhaust Stack Diameter: ___Inches

Engine Make/Model: MACK300 [2VALVE] Miles/Hours: ______ I.D.#: 4
Type of Equipment: GARBAGE COMPACTOR

Fuel Specfic Gravity: ______________ @: ________ (°F)

Barometric Pressure: ______________ inches of Mercury Start Time: ________

| RPM | Exhaust Temp °F | P Inches of $H_2O$ | % CO | HC ppm | % $CO_2$ | % $O_2$ | $NO_x$ |
|---|---|---|---|---|---|---|---|
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Loaned to Baldwine Bobby [illegible] shop [illegible]

Names of Customer Personnel Participating in Test:

______________________ ______________________

Signature of Technicians:

______________________ ______________________

# Carbon Mass Balance Field Data Form

Company: LUSK Location: PRINCSTON Test Date: 7/19/94
Test Portion: Baseline: ______ Treated: ✓ Exhaust Stack Diameter: ___Inches

Engine Make/Model: MACK 4 VALVE 300 Miles/~~Hours~~: 13375 I.D.#: 36
Type of Equipment: GARBAGE COMPACTOR

Fuel Specfic Gravity: .848 @: ______ (°F)

Barometric Pressure: 30.20 inches of Mercury Start Time: 1630

| RPM | Exhaust Temp °F | P Inches of $H_2O$ | % CO | HC ppm | % $CO_2$ | % $O_2$ | $NO_x$ |
|---|---|---|---|---|---|---|---|
| 1700 | 362.8 | .95 | .02 | 5 | 2.06 | 16.9 | |
| | 364.2 | .95 | .02 | 5 | 2.06 | 16.9 | |
| | 365.0 | .95 | .02 | 5 | 2.06 | 16.9 | |
| | 365.8 | .95 AUTO | .02 CAL | 5 | 2.06 | 16.8 | |
| | 360.2 | .95 AUTO | .02 CAL | 6 | 2.06 | 16.9 | |
| | 359.6 | .95 | .02 | 6 | 2.06 | 16.9 | |
| | | | | | | | |
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| | | | | | | | |

Water 182°F

Oil 70 #

✓

Names of Customer Personnel Participating in Test:

______ ______

Treated

Smoke = 3

7/19 #36

Signature of Technicians:

______ ______

# Carbon Mass Balance Field Data Form

Company: LUSK Location: PRINCETON Test Date: 7/19/94
Test Portion: Baseline: ______ Treated: ✓ Exhaust Stack Diameter: ___ Inches

CUMMINS 315
Engine Make/Model: PAYSTAR 5000 Miles/~~Hours~~: 346989 I.D.#: 10
Type of Equipment: INTERNATIONAL

Fuel Specfic Gravity: .848 @: ______ (°F)

Barometric Pressure: 30.19 inches of Mercury Start Time: 1730

| RPM | Exhaust Temp °F | P Inches of $H_2O$ | % CO | HC ppm | % $CO_2$ | % $O_2$ | $NO_x$ |
|---|---|---|---|---|---|---|---|
| 1900 | 392.6 | 1.1 | .02 | 9 | 2.30 | 17.0 | |
| | 392.6 | 1.1 | .02 | 10 | 2.30 | 17.0 | |
| | 392.0 | 1.1 | .02 | 10 | 2.28 | 17.0 | |
| | 387.8 | 1.1 | AUTO .02 | CAL 12 | 2.25 | 16.5 | |
| | 387.4 | 1.1 | .02 | 12 | 2.26 | 16.5 | |
| | 386.4 | 1.1 | .02 | 12 | 2.22 | 16.5 | |
| | 385.0 | 1.1 | AUTO .02 | CAL 13 | 2.20 | 16.6 | |
| | 384.0 | 1.1 | .02 | 13 | 2.20 | 16.6 | |
| | 383.2 | 1.1 | .02 | 13 | 2.20 | 16.6 | |
| | 382.2 | 1.1 | .02 | 13 | 2.20 | 16.6 | |

**Names of Customer Personnel Participating in Test:**

We think the original odometer reading was 331846

Signature [stamp: 7/19 ... 6]

Smoke = 6