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EVALUATION OF FPC-1® FUEL PERFORMANCE CATALYST

AT

Boise Cascade Corporation

REPORT PREPARED BY
FPC Technology
Boise, Idaho

and

UHI Corporation
Provo, Utah

August 10, 1993

Report No. CO 100R

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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. Field and laboratory tests alike indicate a potential to reduce fuel consumption in diesel fleets in the range of 5% to 9%.

This report summarizes the results of controlled back-to-back field tests conducted by BOISE CASCADE CORPORATION, at the CASCADE LUMBER MILL, Cascade, Idaho, with and without FPC-1® added to the fuel. The test procedure applied was the Carbon Balance Exhaust Emission Tests at a given engine load and speed.

EQUIPMENT TESTED

The following equipment were tested:

2 x 988B Loaders
1 x 966C Loader
2 x Model 1006-6 Diesel Hysters
1 x 235C (Track-mount log stacker)

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, CO2, and O2.

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

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 hand held photo tachometer for engine speed (rpm) determination where dash mounted tachometers are not available.

A hydrometer for fuel specific gravity (density) measurement.

A Bacharach True-Spot Smokemeter for determining exhaust smoke density.

A Hewlett Packard Model 42S programmable calculator for the calculation of the engine performance factors.

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 (CO2, CO, HC), oxygen (O2), 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 Appendix 1.

Fuel 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. A significant change in fuel density (measured as its specific gravity) can lead to inaccuracies in the test results, unless corrected for.

Six pieces of equipment were tested for both baseline and treated fuel segments.
Table 1 below summarizes the percent change in fuel consumption documented with the carbon balance on an individual unit basis.

Table 1:
Summary of Carbon Balance Fuel Consumption Changes

Unit	Engine	RPM	% Change Fuel Consumed
5116	CAT 3306	1690	-11.60
5124	CAT 3408	1050	+ 0.67
5120	CAT 3408	1030	- 9.74
5114	CAT 3306	1300	-15.18
5824	PERKINS	2275	-12.88
5825	PERKINS	2260	- 2.06

DISCUSSION

1) Changes in CO and HC

FPC-1® fuel treatment had a positive effect upon CO. Carbon monoxide (CO) was reduced approximately 60 parts per million or 11.7%. Five of the six units tested experienced reductions in CO.

HC emissions increased during the FPC-1 treated fuel test. The NDIR test instrument (SUN SGA-9000) measures HC as hexane gas, a hydrocarbon that is produced in very small concentrations in diesel engines. This gas tends to increase slightly after initial FPC-1 treatment, however, laboratory tests at recognized independent laboratories such as Southwest Research Institute and Systems Control, Inc., verify FPC-1 has no negative effect upon HC emissions once full engine conditioning has taken place. The increase in HC (fleet average of 4 parts per million) may indicate engine conditioning is not complete or may be related to a change in fuel properties. In any case, the increase in hexane gas was only 4 parts per million.

2) Exhaust Odor and Smoke

Exhaust odor (due to unburned fuel) was less noticeable with FPC-1® treatment. Smoke density was visibly reduced. The smoke density test indicated half of the fleet was producing less smoke on FPC-1 treated fuel. The other half remained unchanged. The smoke density test is done while the engines are running at a fixed rpm, but under no load. Although unavoidable, this test condition tends to minimize the smoke density change created by FPC-1 fuel treatment. It was apparent that the engines smoked less when under load.

CONCLUSIONS

1) The fuel consumption change determined by the carbon balance method for the fleet, ranges from + 0.67% to - 15.18%. The fleet average reduction in fuel consumed is approximately 8.5%.

2) Unburned hydrocarbons (HC) increased 4 parts per million, while carbon monoxide (CO) was reduced 11.7% after FPC-1® treatment.

3) Diesel odor and visible smoke were reduced after FPC-1® treatment. The smoke density test confirmed an improving trend in smoke density.

Appendices

CARBON BALANCE METHOD TECHNICAL APPROACH:

A fleet of diesel powered construction equipment owned and operated by BOISE CASCADE CORPORATION was selected for the FPC-1® field test. The fleet was made up of 3 loaders, 2 Hysters, and a

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.

Each vehicle's engine was brought up to operating temperature at a set rpm and allowed to stabilize as indicated by the engine water, oil, and exhaust temperature, and exhaust pressure. No exhaust gas measurements were made until each engine had stabilized at the rpm selected for the test. # 2 Diesel fuel was exclusively used for the diesel fleet throughout the evaluation. Fuel specific gravity and temperature were taken before testing.

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. Rpm and intake air temperature 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). Additional fuel supplied to Cascade after the baseline was also treated.

Throughout the baseline and treated test measurement process, 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 measured during the test, the molecular weight of each constituent, and the temperature and density 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 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. All performance factors are rounded off to the nearest meaningful place in the sample.

Table 2.
Summary of Emissions Data

	Base Fuel				FPC-1® Fuel			
Unit #	**CO**	**HC**	**CO2**	**RPM**	**CO**	**HC**	**CO2**	**RPM**
5116	.030	18.8	4.59	1692	.027	24.5	4.35	1964
5124	.040	7.3	3.74	1048	.030	8.4	3.50	1044
5120	.050	10.0	3.68	1029	.054	12.6	4.01	1029
5114	.040	13.8	3.07	1315	.030	11.6	2.65	1326
5824	.070	28.2	2.94	2275	.064	31.4	2.84	2275
5825	.070	19.9	2.92	2256	.060	33.7	3.07	2257

Table 3
Summary of Ambient Conditions

	Ave. Air Temperature	**Barometric Pressure**
Baseline	54.0 deg F	26.945
Treated	74.8 deg F	27.076

Table 4
Fuel Density (specific gravity) Comparison

	Base Fuel SG	**Treated Fuel SG**	**Correction Factor**
Diesel	.850	.845	1.0059

Calculation of Fuel Consumption Changes

Table 5

5116/1690 RPM

Mwt1	29.3315	Mwt2	29.3094
pf1	134,604	pf2	141,836
PF1	205,223	PF2	227,776

227,776 (1.0059) = 229,120

% Change PF = [(229,120 - 205,223)/205,223](100)

***% Change PF = + 11.6%**

Table 6

5124/1050 RPM

Mwt1	29.2428	Mwt2	29.2073
pf1	164,235	pf2	175,604
PF1	132,520	PF2	130,856

130,856 (1.0059) = 131,628

% Change PF = [(131,628 - 132,520)/132,520](100)

****% Change PF = - 0.67%**

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

Table 7

5114/1315 RPM

Mwt1	29.1680	Mwt2	29.1127
pf1	198,798	pf2	230,273
PF1	350,217	PF2	401,030

401,030 (1.0059) = 403,396

% Change PF = [(403,396 - 350,217)/350,217](100)

***% Change PF = + 15.18%**

Table 8

5120/1030 RPM

Mwt1	29 2414	Mwt2	29.2503
pf1	166,352	pf2	152,687
PF1	117,757	PF2	128,467

128,467 (1.0059) = 129,225

% Change PF = [(129,227 - 117,757)/117,757](100)

***% Change PF = + 9.74%**

Table 9

5824/2275 RPM

Mwt1	29.1520	Mwt2	29.1322
pf1	204,667	pf2	211,806
PF1	412,490	PF2	462,890

462,890 (1.0059) = 465,621

% Change PF = [(465,621 - 412,490)/412,490](100)

***% Change PF = + 12.88%**

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

Table 10

5825/2260 RPM

Mwt1	29.1524	Mwt2	29.1452
pf1	206,383	pf2	196,605
PF1	502,215	PF2	509,548

509,548 (1.0059) = 512,554

% Change PF = [(512,554 - 502,215)/502,215](100)

***% Change PF = + 2.06%**

* As negative change in PF equates to an increase in fuel consumption.

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
Pb = 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:

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

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

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

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

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)

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

d =Exhaust stack diameter in inches
Pv =Velocity pressure in inches of H_20
Pb =Barometric pressure in inches of mercury
Te =Exhaust temperature ^OF

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

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)

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

d = Exhaust stack diameter in inches
Pv = Velocity pressure in inches of H_20
Pb = Barometric pressure in inches of mercury
Te = Exhaust temperature ^oF

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

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:)

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

$$\% \text{ Change PF} = [(116{,}384 - 108{,}115)/108{,}115](100)$$

$$= +7.65$$

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

FPC Technology, Inc.

Fuel Performance Catalyst

2399 So. Orchard, Suite 205 Phone (208) 345-1808 Fax (208) 345-4821 Boise, Idaho 83705

7.0
4.5
3.5
6.0
2.0
6.5

6.00 5.75 ↓ 4.28

CARBON MASS BALANCE FIELD DATA COMPARISON

Company: Boise Cascade Corp. #3/Cascade Baseline Test Date 6-7-93

BASELINE DATA

(Boise) 11:51 a.m.

BP: 26.945 @ 56 °F Ambient Temp: 54 °F

Fuel: 0.85 SG @ 57.8 °F

134,563
+32,667
133,410

	Unit #	RPM	Exhaust Temp.	Exhaust Press.		CO	HC	CO_2	O_2	NO_x	Smoke	
(CAT 235 D)	05116	1692	552.9	1.7	.027	.03	27.5 18.8	4.59	14.9	859	6.0	+11.80 (11.6)
(CAT 988B)	05124	1048	479.1	0.6	.63	.04	8.67 7.3	3.74	16.1	636	6.5	+6.07
(CAT 988 B)	05120	1029	503.7	0.8	.057	.05	12.6 10	3.68	16.3		7.0	+7.80
(CAT 966 C)	05114	1315	367.3	1.04	.03	.04	11.6 13.8	3.07	16.9	213	7.5	+15.38
(HYSTER)	5824	2275	396.5	2.6	.084	.07	31.4 28.2	2.94	17.0	214	5.0	+13.28
(HYSTER)	5825	2256	356.4	1.71	.06	.07	33.7 19.9	2.92	17.1	494	4.0	+12.638 (5.14)
				(.044)	.01		16.33 (20.4)					
5124	29.2888	110,034	122,178		= 11.78							7.64%

135

1.56 - 15.30 (8.74%)
2

227,866 (1.0059) 225,212
227,776 (1.0015) 226,170

A-5 A-3

Hyster 5824

Smoke #1 - 4.5
#2 - 4.5

FPC® TECHNOLOGY, INC.
Boise, Idaho

CARBON MASS BALANCE FIELD DATA FORM

Company: Boise Cascade Corp. #3/Cascade Test Date: 8-3-93

Test Portion: Baseline ☐ Treated ☒

Equipment Tested:

Make Hyster Miles _____ I.D.# _____

Engine Type Model 1006-6 Perkins In-Line 6 Hours 5219.4 I.D.# 5824

Fuel Injection ☒ Naturally Aspirated ☐

Mechanical ☐ Turbocharged ☐

Exhaust Stack Diam 2½ - (3) Inches Straight ☐ Curved ☒

BP: _____ Inches Hg @ _____ °F Ambient Temp: 69.4 °F

Fuel: _____ SG @ _____ °F

Start Time: _____

	RPM	Exh Temp °F	P_v Inch H_2O	CO	HC	CO_2	O_2	Remarks
1	2276							
2	2271	410.6	2.3	.07	31	2.91	16.1	
3	2274	426.4	2.3	07	31	2.88	16.1	
4	2275	429.6	2.4	.07	31	2.84	17.1	
5	2274	433.6	2.4	.06	31	2.84	16.7	
6	2274	431.0	2.2	.06	31	2.83	17.2	
7	2276	428	2.2	.06	32	2.82	16.8	
8	2279	427.6	2.2	.06	32	2.81	16.8	
	~~Average~~ 2275	426.0	2.2	.06	32	2.81	16.8	

Signature of Technicians; _____ Finish Time: _____

2275.4 426.6 2.3 .064 31.4 2.84 16.96

29.1322

211,806

463.078 (1.0052) = 466,875 - 412,450 (13.2%)

5124 9888

6.5 6.5

FPC® TECHNOLOGY, INC.
Boise, Idaho

#1 6.5
#2 6.5

CARBON MASS BALANCE FIELD DATA FORM

Company: Boise Cascade Corp. #3/Cascade Test Date: 8-3-93

Test Portion: Baseline ☐ Treated ☒

Equipment Tested:

Make CAT 988 B Miles _____ I.D.# _____

Engine Type 3408 B CAT Hours 9360 I.D.# 05124

Fuel Injection ☐ Naturally Aspirated ☐

Mechanical ☐ Turbocharged ☐

Exhaust Stack Diam 8 Inches Straight ☐ Curved ☒

BP: 27.088 Inches Hg @ 73 °F Ambient Temp: 66.4 °F

Fuel: _____ SG @ _____ °F

Start Time: _____

	RPM	Exh Temp °F	P_v Inch H_2O	CO	HC	CO_2	O_2	Remarks
1	1054							
2	1049	473.2	.6	.03	6	2.84	16.4	
3	1049	473.2	.6	.03	6	2.91	16.1	
4	1048	482.8	.6	.03	4	2.91	16.7	
5	1053	487	.6	.03	4	2.89	16.5	
6	1049	491.0	.6	.03	6	2.88	16.9	
7	1049	490.2	.6	.03	6	2.85	16.7	
8								
	Average							

Signature of Technicians: _____ Finish Time: _____

5120 4988

#1 7 #2 7

FPC® TECHNOLOGY, INC.
Boise, Idaho

#1 - 7
#2 - 7

CARBON MASS BALANCE FIELD DATA FORM

Company: Boise Cascade Corp. #3/Cascade Test Date: 8-3-93

Test Portion: Baseline ☐ Treated ☒

Equipment Tested:

Make CAT 988 B Miles _____ I.D.# _____

Engine Type 3408 B CAT Hours 9283 I.D.# 05120

Fuel Injection ☒ Naturally Aspirated ☐

Mechanical ☐ Turbocharged ☒

Exhaust Stack Diam 8 Inches Straight ☐ Curved ☒

10.00 BP: 27.098 Inches Hg @ 73 °F Ambient Temp: 66.4 °F

Fuel: .843 SG @ 76.2 °F

Start Time: 9:55 AM.

	RPM	Exh Temp °F	P_v Inch H_2O	CO	HC	CO_2	O_2	Remarks
1	1027	544	.65	.04	6	2.69	16.4	
2	1029	531.2	.65	.04	9	2.68	16.3	
3	1031	557.0	.7	.04	9	2.74	17.3	
4	1032	554	.7	.04	9	2.80	17.1	
5	1032	553.2	.7	.04	8	2.78	17.3	
6	1033	561.0	.7	.04	8	2.73	17.1	
7								
8								
	Average							

Signature of Technicians: _____ Finish Time: _____

CO2 Drifted .12 ?

Hyster 5825 3.5 3.5

Smoke 1 - 3.5 2 - 3.5

FPC® TECHNOLOGY, INC.
Boise, Idaho

CARBON MASS BALANCE FIELD DATA FORM

Company: Boise Cascade Corp. #3/Cascade Test Date: 8-3-93

Test Portion: Baseline ☐ Treated ☒

Equipment Tested:

Make Hyster Miles _____ I.D.# _____

Engine Type Model 1006-6 Perkins In-Line 6 Hours 8352 I.D.# 5825

Fuel Injection ☐ Naturally Aspirated ☐

Mechanical ☐ Turbocharged ☐

Exhaust Stack Diam 2½ - (3) Inches Straight ☐ Curved ☒

BP: _____ Inches Hg @ _____ °F Ambient Temp: _____ °F

Fuel: _____ SG @ _____ °F

Start Time: _____

	RPM	Exh Temp °F	P_v Inch H_2O	CO	HC	CO_2	O_2	Remarks
1	~~2257~~	~~344.4~~	~~1.8~~	~~.06~~	~~33~~	~~3.41~~	~~15.7~~	
2	~~2259~~	~~406.8~~	~~1.6~~	~~.06~~	~~26~~	~~3.25~~	~~15.5~~	
3	~~2259~~	~~410.2~~	~~1.6~~	~~.06~~	~~31~~	~~3.20~~	~~15.5~~	
4	~~2256~~	~~409.6~~	~~1.5~~	~~.06~~	~~31~~	~~3.18~~	~~15.4~~	
5	2257	409.8	1.6	.06	31	3.11	16.3	
6	2259	409.0	1.6	.06	31	3.10	16.3	
7	2257	403.8	1.6	.06	32	3.08	16.3	
8	2259	406.4	1.6	.06	35	3.05	16.3	
	~~Average~~ ~~2258~~ 2253	407.8 407.6	1.6	.06	35	3.05 3.04	16.3	

Signature of Technicians: _____ Finish Time: _____

2257.2 407.4 1.6 .06 33.7 3.07 16.3

29.1452

196,605

505.7 ft³ - (1.0082) = 513,535 - 500,744

#0 05116 CAT 235 C

FPC® TECHNOLOGY, INC.
Boise, Idaho

#1 6
#2 6

CARBON MASS BALANCE FIELD DATA FORM

Company: Boise Cascade Corp. #3/Cascade Test Date: 8-3-93

Test Portion: Baseline ☐ Treated ☒

Equipment Tested:

Make CAT 235 ● C Miles _____ I.D.# _____

Engine Type 3306 CAT Hours 2194 I.D.# 05116

Fuel Injection ☒ Naturally Aspirated ☐

Mechanical ☐ Turbocharged ☒

Exhaust Stack Diam 4 Inches Straight ☒ Curved ☐

BP: _____ Inches Hg @ _____ °F Ambient Temp: _____ °F

Fuel: .845 SG @ 73.2° °F

Start Time: 9:30 AM

	RPM	Exh Temp °F	P_v Inch H_2O	CO	HC	CO_2	O_2	Remarks
1	1693	567.0	1.6	.03	22	4.33	~~14.2~~	
2	1694	573.6	1.55	.03	24	4.37	~~14.1~~	
3	1692	575.6	1.55	.02	25	4.36	15.4	
4	1696	576.2	1.55	.03	26	4.36	15.2	
5	1696	571.6	1.55	.02	25	4.36	15.4	
6	1695	572.6	1.6	.03	25	4.34	15.2	
7	1694.3							
8								
	Average	572.8	1.57	.027	25.5	4.35	15.3	

Signature of Technicians: _____ Finish Time: _____

25.3054
141,636
221,866 (1.0071) = 225,475 - 200,223
(+11.828)

1 - 6.5
2 - 6.5

FPC® TECHNOLOGY, INC.
Boise, Idaho

CARBON MASS BALANCE FIELD DATA FORM

Company: Boise Cascade Corp. #3 Cascade Test Date: 8-3-93

Test Portion: Baseline ☐ Treated ☒

Equipment Tested:

Make CAT 988B Miles _____ I.D.# _____

Engine Type 3408 B CAT Hours 9363 I.D.# 05124

Fuel Injection ☒ Naturally Aspirated ☐

Mechanical ☐ Turbocharged ☒

Exhaust Stack Diam 8 7 Inches Straight ☐ Curved ☒

BP: 27.098 Inches Hg @ 73° °F Ambient Temp: ~~3220~~ P °F

Fuel: _____ SG @ _____ °F

Start Time: 220 PM

Re-Test

	RPM	Exh Temp °F	P_v Inch H_2O	CO	HC	CO_2	O_2	Remarks
1	1051	511.6	.7	.03	6	3.53	16.0	
2	~~1040~~	~~506.8~~	.7	.03	~~9~~	3.41	~~15.8~~	
3	~~1040~~	~~499~~	.7	~~.03~~	~~9~~	~~3.45~~	~~16.6~~	
4	~~1036~~	~~492.6~~	.6	.03	~~9~~	~~3.41~~	~~16.3~~	
5	~~1036~~	~~488.6~~	~~.7~~	.03	~~9~~	3.43	~~16.3~~	
6	1048	478	.8	.03	8	3.57	16.0	
7	1050	495	.8	.03	10	3.54	16.6	
8	1049	490.4	.8	.03	9	3.62	15.9	
	Average							
	1052	499.6	.8	.03	9	3.58	16.0	

29.2125
175,627
129,774

Signature of Technicians: _____ Finish Time: ± 1.005

(3.50) (16.24)

1050 495.8 .78 .03 8.4 3.57 16.10

131,195

(1044) (495.7) (.73) (.03) (8.67)

29.2057
172,254
123,323

127,482
~~131,732~~ - 132,022
~~140,670~~ (1.0094) =
- (6.042)

1-7
2-7

FPC® TECHNOLOGY, INC.
Boise, Idaho

CARBON MASS BALANCE FIELD DATA FORM

Company: Boise Cascade Corp. #3 Cascade Test Date: 8-3-93

Test Portion: Baseline ☐ Treated ☒

Equipment Tested:

Make 988B CAT Miles _____ I.D.# _____

Engine Type 3408 Hours 9286 I.D.# 05120

Fuel Injection ☐ Naturally Aspirated ☐

Mechanical ☐ Turbocharged ☒

Exhaust Stack Diam 87 Inches Straight ☐ Curved ☒

BP: _____ Inches Hg @ _____ °F Ambient Temp: 80.2 °F

Fuel: _____ SG @ _____ °F

R.P.M FLUCTUATING DURING WHOLE TEST Start Time: 3:00 PM

	RPM	Exh Temp °F	P_v Inch H_2O	CO	HC	CO_2	O_2	Remarks
1	1027	547	.6	.06	12	4.23	14.9	
2	1032	550	.6	.06	13	4.05	15.0	
3	1028	553.2	.6	.06	14	4.13	15.7	
4	1034	563	.6	.05	12	4.01	15.1	
5	1025	561.2	.6	.05	12	4.30	14.9	
6	1030	560.8	.6	.05	12	3.97	15.2	
7	1029	562.0	.6	.05	13	4.03	15.7	
8	1029.3	556.9	.6	.054	12.6	4.10	15.21	
	Average					4.01		

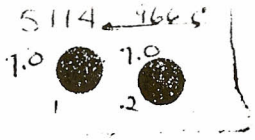
Re-test

Signature of Technicians: _____ Finish Time: _____

28.2507
152,689
128,462 (1.0054) = 129,634

25.2657
149,461
125,850 (1.0094) = 126,938 - 117,757

OPERATOR Couldn't Maintain Constant R.P.M. (±7.80%)



SMOKE SPOT
#1 - 7.0
#2 - 7.0

FPC® TECHNOLOGY, INC.
Boise, Idaho

CARBON MASS BALANCE FIELD DATA FORM

Company: Boise Cascade Corp. #3/Cascade Test Date: 8-3-93

Test Portion: Baseline ☐ Treated ☒

Equipment Tested: 632 − 586 = 46 + 22 = 68 hrs.

Make CAT 966 C Miles _____ I.D.# _____

Engine Type 3306 CAT Hours 632 + new meter I.D.# 05114

Fuel Injection ☒ Naturally Aspirated ☐

Mechanical ☐ Turbocharged ☒

Exhaust Stack Diam 4 Inches Straight ☐ Curved ☒

1-20-P BP: 27.055 Inches Hg @ 86 °F Ambient Temp: _____ °F

Fuel: .845 SG @ 73.2 °F

Start Time: 1:45

	RPM (1318)	Exh Temp °F	P_v Inch H_2O	CO	HC	CO_2	O_2	Remarks
1	~~1318~~			~~.03~~	~~10~~	~~2.72~~	~~16.2~~	
2	1318	364	1.0	.03	10	2.69	15.8	
3	1321	365.6	1.0	.03	10	2.69	15.8	
4	1327	367.0	1.0	.03	13	2.66	17.2	
5	1324	369.4	1.1	.03	12	2.66	17.1	
6	1334	367.6	1.1	.03	12	2.65	17.3	
7	1335	371.2	1.2	.03	12	2.65	17.1	
8	1322	370	1.1	.03	12	2.58	17.1	
	Average							

Signature of Technicians: _____ Finish Time: 2:18

1325.5 367.8 1.07 .03 11.6 2.65 17.2

29.1127

230,273 / 400 scf (1.007) = 403,711 − 350,247 (15.7)