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Locomotive Loadbox Test of FPC-2 Fuel Catalyst

by

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Report prepared by Geneva Steel and FPC International, Inc.

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Abstract

A unique combustion catalyst (FPC-2) marketed by FPC International was subjected to rigorous tests by Geneva Steel, Vineyard, Utah. Phase 1 of the test format involved loadbox tests of two locomotives (before and after FPC-2 fuel treatment) to determine the effect of the catalyst upon fuel consumption, power output and harmful emissions. Phase 2 of the test utilized incorporated air box inspection to determine the effect of the catalyst upon engine component cleanliness.

Test results show the following cost saving and environmental benefits:

(1) Fuel consumption reductions of 4% to 11% (ave. 7.8%).
(2) Smoke reductions of 12% to 18%.
(3) Reduced carbon accumulation on combustion chamber, intake and exhaust system components.

These short term test results confirm immediate economic and environmental benefit to Geneva Steel. These same results also provide conclusive evidence of long term benefit from continual FPC-2 usage. For example, reduced engine smoking will ensure reduced carbon buildup on critical engine and exhaust components, and therefore, improve performance and useful life of these components.

Although not the subject of the above test program, FPC is equally as effective in gasoline powered vehicles and equipment. Laboratory tests provide conclusive evidence that the addition of FPC to gasoline will improve fuel economy 3% to 5%, and reduce regulated emissions. Emissions reductions are most profound for carbon monoxide and carbon particulate (smoke).

I. Introduction

FPC-2™ Fuel Performance Catalyst is a proven fuel additive that reduces fuel consumption and increases engine horsepower. Along with the cost saving effect of reduced fuel consumption, FPC-2™ reduces engine smoke, removes carbon buildup from air boxes, combustion chamber components, and exhaust systems, and reduces "weeping of fuel" from exhaust stacks. Due to reduced smoke and carbon buildup, FPC-2™ virtually eliminates common wayside fires. The same chemistry that provides the initial FPC-2™ cleaning effect, also results in a continual cleaning system. Engine and exhaust components that are typically subject to efficiency robbing carbon deposits (injectors, piston crowns, rings, seats, intake and exhaust ports) are gradually cleaned, and future carbon deposits prevented by utilizing the FPC-2™ fuel treatment.

Geneva Steel proposed a two Phase test of FPC-2™. Phase 1 of the trial of FPC-2™ by Geneva Steel determined the degree of fuel consumption and smoke reduction resulting from the addition of the FPC-2™ catalyst to the # 2 diesel fuel which will fuel locomotives #1102 and #23 while loadbox testing.

The recommended test methodology for determining fuel consumption is the carbon mass balance (CMB). The CMB method measures the carbon containing products of the combustion process (CO_2, CO, HC) found in the exhaust, rather than directly measuring fuel flow into the engine. The method also allows for smoke density and visible emissions determination, which is a critical part of the emissions analysis. This analysis determines combustion efficiency and documents the effect of FPC-2™ upon harmful gaseous emissions.

Phase 2 of the trial will was completed during the engine conditioning period between the baseline fuel loadbox test and the FPC-2™ treated fuel loadbox test, a period of approximately 700 hours (60 days). During Phase 2, Geneva Steel maintenance personnel observed reductions in engine smoking, "weeping of fuel" out exhaust stacks, cleaner air boxes, spark arresters, carbon plugs, and eductor tubes.

II. Carbon Mass Balance Loadbox Test Method

The carbon mass balance eliminates virtually all of the variables associated with field testing for fuel consumption. Instead of measuring fuel flow into the engine (i.e weight or volume of the fuel), measurements are made of the exhaust gases leaving the engine. More precisely, the carbon-containing gases in the exhaust are measured. Since the engines only source of carbon is from the fuel it consumes, the carbon measured in the exhaust must be a direct derivative of the fuel.

Carbon Balance Calculation:

The carbon leaving the engine is primarily Carbon Dioxide (CO_2), Carbon Monoxide (CO), unburned Hydrocarbons (HC), and particulate (smoke). By collecting this data while the engine is operating at a given load and speed, the fuel flow rate into the engine will be accurately determined. When engine load and speed, and compensation for intake pressure and temperature, all of which influence fuel consumption, are reproduced and/or monitored to make appropriate corrections, the carbon balance will be used to confidently determine changes in fuel consumption that may result from the use of a fuel catalyst, such as FPC-2™.

With the carbon balance measurement, engine efficiency can be expressed in terms of fuel mass (grams of carbon) consumed per unit of time (second). Fuel consumption can then be compared to engine power output (brake specific fuel consumption). To calculate any change in engine performance, separate measurements are made with the engine running on base fuel (untreated) and FPC-2™ treated fuel. Any changes are stated as percentage changes from baseline.

The carbon balance also makes possible the determination of the effect of FPC-2™ upon exhaust emissions, principally smoke and carbon monoxide, both of which are regulated by the EPA.

III. Instrumentation

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

1) Sun Electric SGA-9000 non-dispersive infrared (NDIR) four gas analyzer -- measures the volume percentage of CO_2, CO, and O2 in the exhaust, and the parts per million (ppm) of HC.

2) EPA I/M Calibration Gases -- known gases used to internally calibrate the NDIR analyzer.

3) Twenty (20) foot sampling train and stainless steel exhaust gas probe -- inserted into the engine exhaust pipe draws a sample of exhaust gases to the analyzer.

4) Fluke Model 52 hand held digital thermometer and wet/dry thermocouple probe --measures exhaust, ambient, and fuel temperature.

5) Dwyer Magnehelic 2000 Series Pressure Gauge and pitot tube -- measures exhaust air velocity and/or pressure.

6) Monarch Contact/Non-contact digital tachometer and magnetic tape -- measures engine rpm when dash mounted tachometers are unavailable.

7) Hydrometer and flask -- determine fuel specific gravity (density).

8) Loadbox and shunts or multimeter for power output determination

9) Bacharach Truespot Smokespot meter -- determine smoke density in exhaust gases.

10) Barometric pressure-- is determined on site from ambient readings.

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

IV. Procedure

A. Carbon Mass Balance Testing
The following technical approach is observed during the baseline test and the treated fuel test segments:

1) Instruments are calibrated according to accepted protocol.

2) Samples of fuel are drawn from the fuel tank on each locomotive. Using a hydrometer and wet/dry temperature probe, fuel specific gravity is recorded.

3) Each locomotive is tested while stationary and connected to the loadbox. Data will be taken at several throttle notch settings, the combination thereof representing a typical duty cycle. Data is taken only after engine stabilization has taken place, as determined from engine and exhaust temperatures, as well as exhaust gas readings.

4) Engine hours (or mileage) are taken from hour meters installed on the equipment.

5) After engine stabilization, the exhaust gas sampling probe is inserted into the exhaust stream. The Autocal button is depressed and after the LED readouts clear, test personnel take multiple readings of carbon dioxide, carbon monoxide, unburned hydrocarbons, and oxygen, along with engine speed, exhaust temperature and pressure.

6) Periodically, ambient air temperature and pressure are recorded.

7) All data is recorded by Geneva Steel, RELCO, and FPCI technicians until all are confident the information is consistent and reproducible.

8) After completion of the baseline phase, the test fleet fuel will be treated with

FPC-2. All equipment will operate as normal for approximately 400 to 500 hours, at which time the above procedure will be reproduced without alteration.

Power output, load and rpm are used to ensure engine work output is reproduced from test to test. These parameters may also be used to compute engine efficiency (brake specific fuel consumption).

Note: Although it is helpful to lock out auxiliaries that affect horsepower and fuel consumption (such as compressors and cooling fans), it is unnecessary with the carbon balance since all readings are instantaneous, and the instrument can immediately detect any change created by parasitic horsepower drain.

C. Smoke Observations

Using the provisions of 40 CFR Part 60 Appendix A, Method 9, and the Bacharach Smoke Spot method for smoke density determination, smoke opacity and density were determined at each notch position during loadbox testing. The smokespot meter collects smoke particulate onto a 5 micron filter medium, thus darkening the paper. The dark "spot" is visually compared to a calibrated scale and assigned a smoke number. The darker the smoke spot, the higher, and the greater the density of the smoke in the exhaust stack. EPA Method 9 for visible emissions observation (VEO) were also read for the locomotives against a contrasting background.

Smoke emissions were reduced using both methods of smoke density determination.

D. Observation of Carbon Related Maintenance

Many observable benefits are derived from FPC-2™ fuel treatment. Typically, these benefits are realized during what is known as the "engine preconditioning period". After fuel treatment with FPC-2™, the combustion reaction is improved. This leads to the more complete and more efficient combustion of the hydrocarbons making up the fuel. As a result of improved combustion existing carbon deposits are gradually removed from troublesome areas. As long as the engine is mechanically sound, these areas remain clean with continued FPC-2™ use.

Phase 2 involved periodic inspection of air boxes and intake ports and final examination of exhaust stacks and carbody area near exhaust stack openings. These inspections revealed a gradual cleaning effect caused by FPC-2™. Visual inspection of the stacks while the engines are running also revealed reduced engine smoking.

V. Discussion of Results

a. Engine Load

Parameters used to determine power output were reproduced, with the exception of amperage. Engine speed (rpm) and throttle position were identical, as was voltage. Further, exhaust gas temperature and pressure velocity indicated engine power output were at least as high as the baseline. Examination of amp meters by a RELCO electrician revealed the amp meters for both engines were malfunctioning, and may have led to erroneous readings.

b. Fuel Economy

Fuel flow, measured in carbon grams per second, was reduced at every throttle position after FPC-2™ fuel treatment and engine conditioning. The reduction in fuel consumption was greater for the 1102 than the 23. This is likely due to several factors. First, the 23 was run fewer hours during the test on FPC-2 treated fuel, and may not have reached full engine conditioning. Second, the 23 has over 20,000 engine hours compared to the 1102's 3,000 engine hours. The 23 exhibited more fuel weeping and carbon encrustation on exhaust stacks and air boxes. Therefore, the 23 may suffer from greater mechanical deficiencies that are difficult for FPC-2™ to overcome, especially in a test of short tenure.

Smoke reductions were also not as great in the 23, again possibly a result of losses in efficiency created by the high hours and probable mechanical shortcomings of the engine.

c. Air Box and Exhaust Stack Inspections

Both the air boxes and the exhaust stacks were cleaner after extended FPC-2™ usage. Carbon and oil buildup on intake port webbing was gradually removed, exposing bare metal. Exhaust stacks were also cleaner after several hundred hours of FPC-2™ treated fuel use. Photographs of the air box area of one test locomotive are attached in Appendix 4.

None of the locomotives operated by Geneva Steel are turbocharged, nor have carbon plug traps or spark arresters, therefore, the effect of the catalyst on these components could not be determined. However, it is reasonable to assume that, if the catalyst could reduce carbon buildup on exhaust stacks and air box ports, it would have a similar effect upon eductor tubes, turbos, traps and arresters.

d. Engine Teardown

Several months after initiating full system use of FPC-2™, the engine from one of the switchers was taken down and new power assemblies installed. This provided Geneva Steel and RELCO with an opportunity to observe the cleaning affect of FPC-2 treated fuel upon combustion chamber components. Inspection of the power assemblies showed much cleaner exhaust ports and pistons, and ring zone areas.

VI. Conclusions

The loadbox test documented treatment of the diesel fuel powering the two subject EMD locomotive engines had the following positive effect on engine performance:

(1) Reduced fuel consumption (averaging 7.8%) at the same horsepower, throttle, and rpm settings.
(2) Reduction of engine smoking (averaging 16.5%).
(3) Reduced carbon buildup on intake and exhaust systems.

Appendix 1.   Raw Data Sheets

Appendix 2 Carbon Flow Calculations

FPC International **CARBON BALANCE RESULTS**

COMPANY :	Geneva	LOCATION :	Vineyard
EQUIPMENT :	Locomotive	UNIT NR. :	No. 23
ENG. TYPE :	EMD	MODEL :	SW1200
RATING :	1200 hp	FUEL :	#2D

BASELINE TEST **DATE : 15/10/97**

ENG. HOURS :	20111	ENG. RPM:	461 (N4)
AMB. TEMP (C) :	11.11	STACK(mm):	256
BAROMETRIC(mb):	1017	LOAD:	277 hp

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	454.04	454.04	454.04	454.04	454.04	454	0.00
EXHST TEMP (C):	215.4	217.4	214.8	214.9	214.6	215	0.53
HC (ppm) :	2	3	3	2	3	2.6	21.07
CO (%) :	0.01	0.01	0.01	0.01	0.02	0.012	37.27
CO2 (%) :	3.42	3.41	3.44	3.40	3.41	3.42	0.44
O2 (%) :	16.20	16.20	16.10	16.30	16.30	16.22	0.52
CARB FLOW(g/s):	15.254	15.181	15.356	15.172	15.268	15.246	0.49
REYNOLDS NR. :	8.71E+04						

TREATED TEST **DATE : 4/12/97**

ENG. HOURS :	20811	ENG. RPM:	460(N4)
AMB. TEMP (C) :	0.66	STACK(mm):	256
BAROMETRIC(mb):	1011	LOAD:	323.5 hp

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	416.2	416.2	416.2	416.2	416.2	416	0.00
EXHST TEMP (C):	210.7	213.3	211.2	212.4	210.8	212	0.53
HC (ppm) :	0	0	0	0	1	0.2	223.61
CO (%) :	0.01	0.01	0.00	0.01	0.02	0.010	70.71
CO2 (%) :	3.33	3.34	3.33	3.33	3.32	3.33	0.21
O2 (%) :	16.00	15.80	15.80	15.80	15.80	15.84	0.56
CARB FLOW(g/s):	14.246	14.252	14.197	14.223	14.249	14.233	0.16

REYNOLDS NR. : 8.34E+04 TOTAL HOURS ON TREATED FUEL : 700

PERCENTAGE CHANGE IN FUEL CONSUMPTION ((TREATED-BASE)/BASE*100) : **-6.6 %**

REMARKS:

FPC International **CARBON BALANCE RESULTS**

COMPANY :	Geneva	LOCATION :	Vineyard
EQUIPMENT :	Locomotive	UNIT NR. :	No. 23
ENG. TYPE :	EMD	MODEL :	SW1200
RATING :	1200 hp	FUEL :	#2D

BASELINE TEST **DATE : 15/10/97**

ENG. HOURS :	20111	ENG. RPM:	600 (N6)
AMB. TEMP (C) :	11.11	STACK(mm):	256
BAROMETRIC(mb):	1011	LOAD:	715 hp

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	832.4	832.4	832.4	832.4	832.4	832	0.00
EXHST TEMP (C):	307.2	306	306.7	305.8	307	307	0.20
HC (ppm) :	5	4	4	3	5	4.2	19.92
CO (%) :	0.02	0.02	0.02	0.02	0.02	0.020	0.00
CO2 (%) :	4.70	4.74	4.72	4.70	4.70	4.71	0.38
O2 (%) :	14.60	14.40	14.30	14.30	14.20	14.36	1.06
CARB FLOW(g/s):	26.011	26.258	26.135	26.042	26.023	26.094	0.40

REYNOLDS NR. : 1.08E+05

TREATED TEST **DATE : 4/12/97**

ENG. HOURS :	20811	ENG. RPM:	599
AMB. TEMP (C) :	0.66	STACK(mm):	256
BAROMETRIC(mb):	1011	LOAD:	622hp

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	794.6	794.6	794.6	794.6	794.6	795	0.00
EXHST TEMP (C):	313.6	317.8	325.6	321.9	321.2	320	1.42
HC (ppm) :	0	0	1	1	1	0.6	91.29
CO (%) :	0.02	0.02	0.03	0.02	0.02	0.022	20.33
CO2 (%) :	4.70	4.67	4.68	4.62	4.65	4.66	0.65
O2 (%) :	13.60	13.40	13.60	13.40	13.40	13.48	0.81
CARB FLOW(g/s):	25.277	25.031	24.973	24.682	24.856	24.964	0.88

REYNOLDS NR. : 1.04E+05 TOTAL HOURS ON TREATED FUEL : 700

PERCENTAGE CHANGE IN FUEL CONSUMPTION ((TREATED-BASE)/BASE*100) : **-4.3 %**

REMARKS:

FPC International **CARBON BALANCE RESULTS**

COMPANY :	Geneva	LOCATION :	Vineyard
EQUIPMENT :	Locomotive	UNIT NR. :	No. 1102
ENG. TYPE :	EMD	MODEL :	SW1500
RATING :	1500 hp	FUEL :	#2D

BASELINE TEST **DATE : 15/10/97**

ENG. HOURS :	2797	ENG. RPM:	500(N4)
AMB. TEMP (C) :	15.45	STACK(mm):	256
BAROMETRIC(mb):	1018	LOAD:	521 hp

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	416.2	416.2	454	454	454	439	4.72
EXHST TEMP (C):	279.2	278.7	277.1	280.9	280.3	279	0.53
HC (ppm) :	2	4	5	2	5	3.6	42.13
CO (%) :	0.00	0.01	0.00	0.00	0.01	0.004	136.93
CO2 (%) :	4.22	4.25	4.25	4.25	4.25	4.24	0.32
02 (%) :	15.70	15.40	15.70	15.40	15.60	15.56	0.97
CARB FLOW(g/s):	16.901	17.077	17.818	17.753	17.810	17.472	2.55
REYNOLDS NR. :	8.05E+04						

TREATED TEST **DATE : 4/12/97**

ENG. HOURS :	3400	ENG. RPM:	500 (N4)
AMB. TEMP (C) :	3.1	STACK(mm):	256
BAROMETRIC(mb):	1011	LOAD:	521 hp

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	416.2	416.2	435.1	435.1	435.1	428	2.42
EXHST TEMP (C):	272.1	274.9	276.2	277.6	278.1	276	0.87
HC (ppm) :	0	0	1	0	2	0.6	149.07
CO (%) :	0.01	0.01	0.00	0.01	0.01	0.008	55.90
CO2 (%) :	3.80	3.78	3.80	3.79	3.80	3.79	0.24
02 (%) :	14.80	14.80	14.70	15.20	15.20	14.94	1.61
CARB FLOW(g/s):	15.315	15.196	15.563	15.536	15.574	15.437	1.11
REYNOLDS NR. :	7.95E+04		TOTAL HOURS ON TREATED FUEL :			603	

PERCENTAGE CHANGE IN FUEL CONSUMPTION ((TREATED-BASE)/BASE*100) : **-11.6 %**

REMARKS:

FPC International **CARBON BALANCE RESULTS**

COMPANY :	Geneva	LOCATION :	Vineyard
EQUIPMENT :	Locomotive	UNIT NR. :	No. 1102
ENG. TYPE :	EMD	MODEL :	SW1500
RATING :	1500 hp	FUEL :	#2D

BASELINE TEST **DATE : 15/10/97**

ENG. HOURS :	2797	ENG. RPM:	644(N6)
AMB. TEMP (C) :	15.45	STACK(mm):	256
BAROMETRIC(mb):	1018	LOAD:	861 hp

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	870.2	870.2	870.2	870.2	870.2	870	0.00
EXHST TEMP (C):	386.8	386	386.3	386	392.5	388	0.72
HC (ppm) :	9	10	9	8	9	9.0	7.86
CO (%) :	0.06	0.07	0.06	0.07	0.07	0.066	8.30
CO2 (%) :	5.58	5.58	5.59	5.57	5.56	5.58	0.20
O2 (%) :	15.70	13.30	13.30	13.30	13.20	13.20	9.49
CARB FLOW(g/s):	29.874	29.998	29.987	29.939	29.745	29.909	0.35
REYNOLDS NR. :	1.04E+05						

TREATED TEST **DATE : 4/12/97**

ENG. HOURS :	3400	ENG. RPM:	638(N6)
AMB. TEMP (C) :	3.1	STACK(mm):	256
BAROMETRIC(mb):	1011	LOAD:	852 hp

	TEST 1	*TEST 2*	*TEST 3*	*TEST 4*	*TEST 5*	AVERAGE	% ST.DEV
PRES DIFF (Pa):	870.2	870.2	870.2	870.2	870.2	870	0.00
EXHST TEMP (C):	378.3	379.4	380.8	382.7	382.6	381	0.51
HC (ppm) :	13	14	14	14	14	13.8	3.24
CO (%) :	0.06	0.06	0.06	0.11	0.10	0.078	31.92
CO2 (%) :	5.09	5.01	5.05	5.09	5.08	5.06	0.68
O2 (%) :	12.90	13.00	12.90	12.90	12.80	12.90	0.55
CARB FLOW(g/s):	27.439	26.994	27.179	27.618	27.516	27.349	0.94
REYNOLDS NR. :	1.04E+05		TOTAL HOURS ON TREATED FUEL :			603	

PERCENTAGE CHANGE IN FUEL CONSUMPTION ((TREATED-BASE)/BASE*100) : **-8.6 %**

REMARKS:

Appendix 3 Smoke Data Table

Table 1. Comparison of Engine Exhaust Smoke Density

Locomotive No.	Notch Position	Date	Smoke Number
1102	4	10-15	6.0
1102	5	10-15	8.0
23	4	10-16	6.5
23	6	10-16	7.0
1102	4	12-04	5.0
1102	5	12-04	6.5
23	4	12-04	5.5
23	6	12-04	6.5

Note: The smoke density data above indicate engine smoking was reduced 18% in Unit 1102 and 12% in Unit 23 after several hundred hours of FPC-2™ fuel treatment.