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EVALUATION OF PERFORMANCE OF FPC FUEL ADDITIVE IN AN EMD F59PH LOCOMOTIVE

FINAL TEST REPORT

Prepared for
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(Go Transit PO#: 021104-0)

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EXECUTIVE SUMMARY

The FPC fuel additive was evaluated in an EMD F59PH locomotive of Go Transit to determine fuel economy and emissions benefits of using additive-treated fuel over regular 2D diesel fuel (baseline fuel). The FPC treated fuel test was conducted first since the locomotive ran with this additive for more than six (6) months. Triplicate runs were performed to both the FPC and the baseline fuel test. A preconditioning run was done before the baseline fuel test. The locomotive was operated at low idle, notch-5 and notch-8 at each run of the FPC and the baseline fuel test. Engine operating parameters, fuel consumption and emissions data were collected during the runs. Average engine brake specified fuel consumption and AAR 3-mode duty-cycle weighted exhaust emissions (CO and NOx) from the triplicate tests are obtained, Test results indicated that FPC additive improves baseline fuel consumption by up to 7% and reduces baseline CO and smoke emissions by 2.8% and 5.8% (at notch 8) respectively. A slight increase of NOx emissions with FPC fuel was also observed.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

AAR	Association of American Railroads
ASTM	American Society for Testing and Materials
BSFC	Brake-Specific Fuel Consumption
C_xH_y	Combustibles
CO_2	Carbon dioxide
CO	Carbon monoxide
EMD	Electro-Motive Division of General Motors Corp.
EPA	Environmental Protection Agency (U.S.)
ESDC	Engine Systems Development Centre, Inc.
NOX	Oxides of nitrogen
SFAT	Simplified Fuel Additive Test
SD	Standard Deviation
SwRI	Southwest Research Institute

1.0 INTRODUCTION

The FPC fuel additive was evaluated in an EMD F59PH locomotive of Go Transit at Engine Systems Development Centre (ESDC) on Feb. 11, 03. The objective of the test was to determine effects of the additive on the locomotive engine performance and emissions. A description of the test approach and test results is presented in this report.

2.0 TECHNICAL APPROACH

2.1 Evaluation Test Procedure

A test program was developed based on RP-503 test procedure [1], AAR 3-mode test procedure and Simplified Fuel Additive Test (SFAT) protocol [2] for evaluating the FPC fuel additive, consisting of two steps:

Step 1: Fuel Properties – The purpose of these tests is to evaluate the effects of the additives on limiting fuel specification requirements. The physical and chemical fuel properties of the baseline fuel and FPC-treated fuel are checked using ASTM methods.

Step 2: Locomotive Test – To determine the effects of the FPC treated fuel on performance and exhaust emissions of the locomotive engine (EMD 12-710G3A). Triplicate runs were conducted on both the baseline and the FPC-treated fuel. Each run sequence consisted of operating at low idle, notch-5 and notch-8 for total 1.5~2 hours. During the runs, engine operating parameters such as engine cooling water temperature, lube oil temperature were maintained as close as possible for the same test mode. Fuel consumption, engine brake horsepower and exhaust emissions were recorded for comparison analysis.

2.2 Test Locomotive

The locomotive tested in this project was a F59PH passenger locomotive Go Transit road number 548 (Figure 1) which was originally manufactured in 1990 by Electro-Motive Division (EMD) of General Motor Corporation. The unit was equipped with a 3200hp EMD 12-710G3A diesel engine. Except for a new crankshaft which was installed by CAD Rail Services, no other engine component changes were applied before being shipped to ESDC.

2.3 Test Fuel

Regular low sulfur 2D diesel fuel from PETRO-CANADA was used as baseline fuel. A storage tank (1000 liter) was prepared for the FPC treated fuel. The treatment was in accordance with the procedure provided by the additive manufacture. Baseline and additive-treated fuel properties were determined before the test began and are given in the next section.

Figure 1. EMD Model F59PH Passenger Locomotive for the Test

2.4 EMD Engine Power Measurement

Instead of using the locomotive self-load feature, a separate load bank was employed. Engine gross brake horsepower was determined by direct measurement of the main generator voltage and current, plus auxiliary power values. (auxiliary generator, traction motor blower and radiator fans) obtained by following published manufacture procedures. The air compressor was unloaded during the test. In calculating main generator power output, a constant alternator efficiency of 93.8% was used for all the test points. Recorded gross brake horsepower was corrected to AAR standard conditions for calculating the brake specific fuel consumption (BSFC) and indicated power values were used to determine specific emissions rates.

2.5 Fuel Consumption Measurement

A weighing tank and load cell system was used to measure fuel consumption rates. The tank has a volume of approximate 400 liters sufficient to complete a test run. Fuel consumption rates (twenty second averages) were recorded for a minimum 2 minutes to obtain a fuel consumption value at each test point. A heat exchanger was applied to ensure a constant fuel temperature during the test. Accuracy of the fuel consumption system is ±0.05% of reading.

2.6 Exhaust Emissions Measurements

An exhaust stack extension was installed in which a probe was fitted for gaseous emissions sampling (Figure 2). The gas samples were drawn from the exhaust stack via a high-flow pump assembly with an in-line water trap and particulate filter for proper conditioning prior to the electrochemical gas sensors. The analyzer is capable of detecting concentrations of carbon monoxide (CO), oxygen (O_2), combustibles (C_xH_y), nitric oxide (NO), and nitrogen dioxide (NO_2), including carbon dioxide (CO_2). The accuracy of each sensor is within 2% of reading.

On the top of the stack, an opacity smoke meter adaptor was mounted, the smoke meter aligned with the long axis of the rectangular exhaust stack (Figure 2). The center of the light beam to the outlet of the stack extension is 5±1 inch. Smoke opacity signals were transferred to a control unit, which was located in the engine test control room, through a 45-feet cable. A computer program was used to record smoke opacity data at rate of 100 samples per second with a response time of 0.25 seconds. The linearity of the smoke meter is 1% from 0-100% opacity

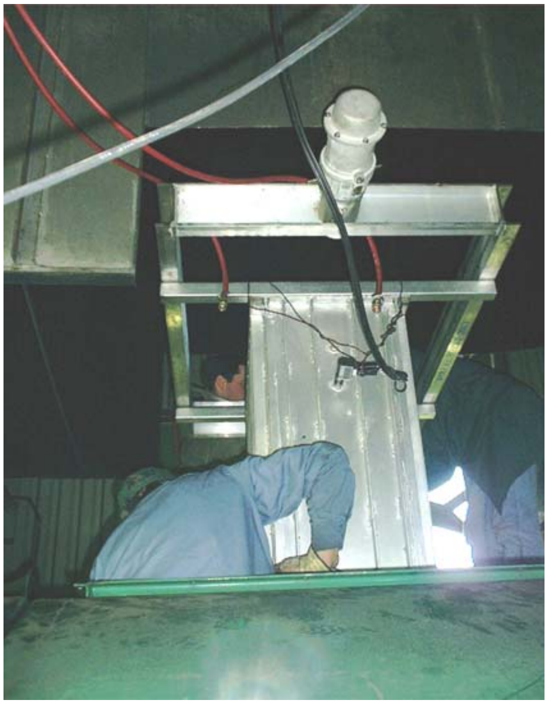

Figure 2. Exhaust Stack Extension and Sampling Systems

3.0 TEST RESULTS

Chemical analysis - The baseline 2D diesel fuel and the FPC-treated fuel properties were tested and shown in Table 1. The properties of treated fuel are very similar to that of the baseline fuel. This agrees well with SwRI's evaluation test results [3] for the same fuel additive.

Table 1: Baseline Fuel and FPC-Treated Fuel Properties

Analysis	Units	Baseline	Treated Fuel
Ash	%	<0.001	<0.001
Cetane Index		46.5	45.5
Density at 15C	kg/L	0.835	0.833
Flash Point, Closed Cup	C	65	64
Pour Point	C	-36	-30
Cloud Point	C	-23	-22
Conradson Carbon Residue	%	0.02	0.03
Particulate Contamination	mg/L	0	0
Sulfur	%p/p	0.03	0.03
Neutralization	mgKOH/g	0.05	0.06
Heat of Combustion	kj/kg	45456	45400
Water and Sediment	%v/v	0.0041	0.0095
Copper Strip Corrosion		1A	1B
Viscosity @ 40 C	cSt	2.1	2.1
Distillation			
IBP	C	164	159
10%	C	190	188
50%	C	244	238
90%	C	309	300

Engine operating parameters - Values recorded during the FPC and 2D diesel fuel test are given in Table 2. Engine coolant, lube oil and fuel temperatures were maintained as constant as possible for the comparative test point. The variation of temperatures between FPC fuel and baseline fuel tests for the same set points are within the limits specified in the RP503.

Table 2: Engine Operating Parameters of FPC Fuel and Baseline Fuel Test

Notch	Test Run No.	Engine Speed (rpm)	Brake Horse-Power (HP)*	Coolant Temp. Eng. Out (°F)	Intake Air Temp. (°F)	Oil Temp. Eng. Out (°F)	Fuel Temp. Eng. In (°F)
Low Idle	#1/3	206	8	161	46	185	80
	#2/3	200	8	167	46	192	81
	#3/3	208	8	166	52	185	80
5	#1/3	654	1437	170	46	190	88
	#2/3	647	1424	179	45	190	88
	#3/3	655	1439	173	50	190	86
8	#1/3	903	3281	179	45	208	102
	#2/3	904	3288	177	45	205	95
	#3/3	905	3271	178	50	203	99
2D Diesel Fuel							
Notch	**Test Run No.**	**Engine Speed (rpm)**	**Brake Horse-Power (HP)***	**Coolant Temp. Eng. Out (°F)**	**Intake Air Temp. (°F)**	**Oil Temp. Eng. Out (°F)**	**Fuel Temp. Eng. In (°F)**
Low Idle	#1/3	201	8	171	50	176	88
	#2/3	201	8	166	63	182	91
	#3/3	208	8	164	55	190	81
5	#1/3	654	1433	180	45	190	95
	#2/3	655	1453	173	61	194	102
	#3/3	654	1430	171	45	190	93
8	#1/3	898	3253	181	48	208	102
	#2/3	898	3295	172	48	203	86
	#3/3	905	3287	182	45	201	93

Note: *- Corrected to AAR standard conditions.

Fuel economy - In order to shorten the preconditioning time, the engine was operated at notch-8 “load test #1” (high fuel through put) with the baseline fuel for 12 hours, During this run engine fuel consumption rates were monitored and BSFC values were calculated and plotted in terms of BSFC versus test hours (Figure 3). Results indicate that after the preconditioning BSFC increased about 2.3% of the initial preconditioning BSFC value.

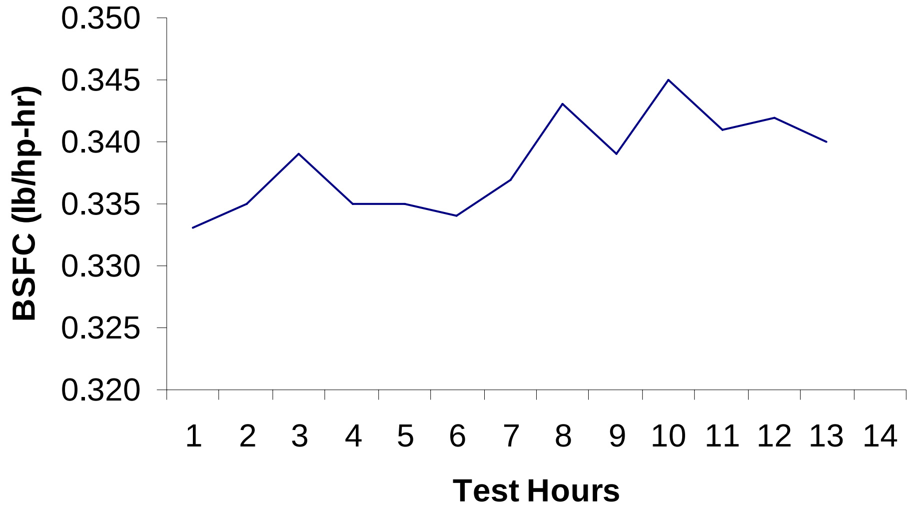

Figure 3. BSFC Values for Preconditioning Test (notch 8 of load test #1)

Engine brake specific fuel consumption values, after the preconditioning period, of FPC and baseline fuel were calculated as shown in Table 3. Results indicate that the FPC improves baseline brake fuel consumption at low idle and notch-8 by 7% and 2.5% respectively. The BSFC change at notch-5 is within repeatability and experimental errors and is considered non-significant. The baseline BSFCs obtained were found similar to the published data [4] for the same type of locomotive.

Table 3: Comparison of BSFC Values of FPC Fuel and Baseline Fuel Test

Notch	Test Run No.	BSFC (lb/hp-hr)		Changes (%)*
		FPC Treated Fuel	Baseline Fuel	
Low Idle	#1/3	3.260	3.200	
	#2/3	3.142	3.350	
	#3/3	2.960	3.510	
	Mean	**3.120**	**3.353**	**-7.0**
	S.D./Mean (%)	**4.80**	**4.60**	****
5	#1/3	0.342	0.359	
	#2/3	0.352	0.344	
	#3/3	0.340	0.341	
	Mean	**0.344**	**0.348**	**-1.0**
	S.D./Mean (%)	**1.87**	**2.76**	****
8	#1/3	0.326	0.337	
	#2/3	0.330	0.333	
	#3/3	0.332	0.343	
	Mean	**0.329**	**0.338**	**-2.5**
	S.D./Mean (%)	**0.82**	**1.48**	****

Note: * - Changes (%) = (Value of FPC fuel – Value of baseline fuel)/(Value of baseline fuel).

Exhaust emissions - Raw gaseous emissions were converted to specific values. The AAR 3-mode duty-cycle was used to calculate the weighted emissions. The weighing factors applied are 50%, 25% and 25% for low idle, notch-5 and notch-8 respectively. Results are given in Table 4. The CO value for FPC treated fuel decreases approximately 2.8% and the quantity of NOx increases slightly compared to that of the baseline.

Table 4: Comparison of Exhaust Emissions of FPC Fuel and Baseline Fuel Test

Emissions	Test Run No.	FPC Treated Fuel	Baseline Fuel	Changes (%)*
CO (g/hp-hr)	#1/3	1.32	1.37	
	#2/3	1.35	1.35	
	#3/3	1.35	1.40	
	Mean	**1.34**	**1.38**	**-2.8**
	S.D./Mean (%)	**1.29**	**1.80**	****
NOx (g/hp-hr)	#1/3	11.6	11.4	
	#2/3	11.4	11.0	
	#3/3	11.3	11.2	
	Mean	**11.4**	**11.2**	**1.8**
	S.D./Mean (%)	**1.33**	**1.78**	****

Note: * - Changes (%) = (Value of FPC fuel – Value of baseline fuel)/(Value of baseline fuel).

Measured smoke opacity values were normalized using the formula provided in section 92.131 of 40CFR part 92 [5]. Smoke opacity data for the FPC treated fuel and baseline fuel tests are given in Table 5. Smoke values of treated fuel show good agreement with that of the baseline fuel for low idle and notch-5, however a 5.8% increase in opacity with the baseline fuel was detected at notch-8.

Table 5: Comparison of Smoke Opacity of FPC Fuel and Baseline Fuel Test

Notch	Smoke Opacity (Steady-State)		Changes (%)*
	FPC Treated Fuel	Baseline Fuel	
Low Idle	3	3	0.0
5	9	9	0.0
8	16	17	-5.8

Note: * - Changes (%) = (Value of FPC fuel – Value of baseline fuel)/(Value of baseline fuel).

4.0 CONCLUSIONS

1. The FPC improves fuel consumption depending on the locomotive operating mode, at notch #8 the improvement is about 2.5% of the engine running on 2D diesel fuel.
2. With application of FPC treated fuel, engine CO and smoke emissions were improved by 2.8% and 5.8% (at notch-8) respectively. Small increase of NOx was also observed.

5.0 RECOMMENDATION

The following additional work is recommended:

1. This report covers the assessment of one locomotive therefore to obtain a more accurate assessment of Go Transits locomotive fleet, a representative fleet sample should be evaluated.
2. The effects of the FPC additive to the head-end power (HEP) engine should be investigated.

REFERENCES

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