THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

SOUTHERN RESEARCH INSTITUTE

ETV Joint Verification Statement

TECHNOLOGY TYPE:	Diesel Fuel Additive
APPLICATION:	On-road and Off-road Heavy-duty Diesel Engines
TECHNOLOGY NAME:	Diesel Fuel Catalyzer
COMPANY:	EnviroFuels, L.P.
ADDRESS:	1111 Bagby, Suite 4900 Houston, Texas 77002
E-MAIL:	etvinfo@envirofuelslp.com

The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The program's goal is to further environmental protection by accelerating the acceptance and use of these technologies. ETV achieves this goal by providing high-quality, peer-reviewed performance data to technology designers, purchasers, distributors, financiers, permitters, users, and the public.

ETV works in partnership with recognized standards and testing organizations, stakeholder groups that consist of buyers, vendor organizations, and permitters, and with the full participation of individual technology developers. The program evaluates technology performance by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests, collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure generation of defensible data with known quality EPA's ETV partner, Southern Research Institute, operates the Greenhouse Gas Technology Center (GHG Center) as one of several ETV organizations in cooperation with EPA's National Risk Management Research Laboratory. The GHG Center collaborated with EnviroFuels, L.P. (EnviroFuels) to evaluate the effects of their diesel fuel additive, the Diesel Fuel Catalyzer (catalyzer).

EnviroFuels has stated that heavy-duty on- and off-road diesel engines are the catalyzer's intended market. Preliminary tests conducted by EnviroFuels have indicated that the catalyzer, used as recommended, has potential to reduce fuel consumption and corresponding carbon dioxide (CO_2) emissions, nitrogen oxide (NO_X) emissions, and total unburned hydrocarbon (THC) emissions. This verification's goal was to assess the additive's performance improvement in a diesel railroad locomotive.

TECHNOLOGY DESCRIPTION

The catalyzer is a patented technology that EnviroFuels claims improves operational efficiency of large diesel engines through three processes: cleaning, surface friction reduction, and fuel combustion improvements.

According to EnviroFuels, laboratory tests have shown that metal surfaces treated with the catalyzer have a lower coefficient of friction and lower oxygen reactivity. Additional tests have demonstrated a greater efficiency and cumulative heat release during combustion of catalyzer-treated fuel as opposed to untreated fuel. EnviroFuels states that the combination of these processes combine in the engine combustion chamber to produce increased fuel efficiency, reduced emissions, and reduced exhaust gas temperatures.

EnviroFuels indicates that six to eight weeks of regular service are required from the initial fuel treatment for the performance improvements to be fully realized in locomotive service. During that break-in period, EnviroFuels recommends an initial dosing rate of 640:1 in most locomotive applications. After that, the fuel must be treated at the normal 1280:1 ratio on an ongoing basis to maintain the effects.

VERIFICATION DESCRIPTION

The GHG Center designed the verification to quantify a diesel freight locomotive's performance before and after administration of the catalyzer. The test locomotive is an EMD Model GP-40-3 which was built in 1980 and remanufactured to Title 40 CFR 92 Tier 0 standards in 2003. Its powerplant is an EMD 645 E3 two-cycle diesel engine rated at 3000 brake horsepower (bhp). This locomotive, a variant of the GP40 series, is representative of the most common pre-1990 line-haul locomotive in the current U.S. fleet. A transportable resistive load bank simulated train resistance while the locomotive was stationary at the siding. Tests occurred at the St. Lawrence and Atlantic Railroad (SLA), a division of Genesee and Wyoming, Inc., near Auburn, ME. SLA provided the test locomotive, fuel, resistive load bank, plant facilities, technical, mechanical, and managerial support.

The locomotive can operate at two idle and eight power delivery capacities, or "notches." Title 40 CFR 92 federal test procedures (FTP) were the basis for the field work except that fuel consumption was not measured directly according to the FTP. This represented a significant departure from the test plan, but the results are valid for the baseline-to-treated fuel comparisons. Title 40 CFR 60 Appendix A, Method 2 volumetric flow traverses combined with the carbon balance method described in Title 40 CFR 86.1392 provided the fuel consumption data. This verification test was designed to quantify:

- brake-specific fuel consumption rates, $BSFC_j$, for baseline and treated fuel, and the change, $\Delta BSFC_j$, for each notch j, gallons per brake horsepower hour (gal/bhp-h)
- line-haul and switch duty-cycle weighted brake-specific fuel consumption rates, $BSFC_{DC}$, and the change, $\Delta BSFC_{DC}$, gal/bhp-h
- brake-specific mass emission rates, E_{ij}, for baseline and treated fuel, and the change, ΔE_{ij}, for each pollutant or GHG species i at each notch j, grams per brake horsepower hour (g/bhp-h)
- line-haul duty-cycle weighted brake-specific mass emission rates, E_{iDC}, and the change, ΔE_{iDC} for each emitted pollutant or GHG species i, g/bhp-h

Emissions measured during the tests were:

- CO_2
- carbon monoxide (CO)
- NO_X
- total hydrocarbons (THC)
- smoke opacity
- total particulate matter (TPM)

The primary locomotive parameters of concern were:

- main generator voltage
- main generator current
- engine fuel consumption
- cooling fan power consumption

Testing began with installation of monitoring equipment while technicians were conducting the locomotive's normal periodic maintenance. Baseline testing started on August 16, 2004 and included six valid test runs. At the completion of the baseline tests, SLA personnel administered the catalyzer to the fuel remaining in the locomotive's belly tank. SLA also enabled a skid-mounted dosing pump which would inject a controlled amount of catalyzer into the fuel stream during each subsequent locomotive refueling event. All fuel used during the following break-in period was treated according to EnviroFuels specifications.

The break-in period, which incorporated the locomotive's normal over-the-road operations, extended from August 21 through October 23, 2004. The locomotive required no maintenance and consumed approximately 35,000 gallons of treated fuel during this period. At EnviroFuels' recommendation, SLA changed the dosing ratio from approximately 640:1 to approximately 1280:1 on October 10. This allowed the locomotive to burn approximately 6,700 gallons of fuel at the latter ratio prior to the treated fuel test runs. Treated fuel test runs began on October 24, 2004 and incorporated six valid test runs.

TECHNOLOGY PERFORMANCE

Brake-specific fuel consumption (BSFC) and brake-specific gaseous emissions showed statistically significant improvements at the majority of the operating notches. Line-haul duty cycle-weighted BSFC and gaseous emissions (except for NO_X, which was not statistically significant) also improved. Switch duty cycle-weighted BSFC and all gaseous emissions showed statistically significant improvements. TPM emissions, however, increased during the treated fuel tests. The results reported here represent the BSFC and emission rate changes seen during the test locomotive's operations under field conditions at the host facility. These results may differ from those using other locomotives, test methods, or host facilities.

The following table presents the changes between the baseline and treated fuel BSFC as gallons per brake horsepower hour (gal/bhp-h) and for brake-specific emissions as grams per brake horsepower hour (g/bhp-h). Positive numbers indicate a BSFC improvement or emission rate increase. Negative numbers indicate an emission rate decrease. For example, notch 2 BSFC improved by 0.009 ± 0.003 gal/bhp-h, CO emissions decreased by 0.20 ± 0.07 g/bhp-h, and TPM increased by 0.09 ± 0.04 g/bhp-h. Uncertainty values are the 95 percent confidence interval about the mean result.

BSFC and Brake-Specific Emission Rate Change, Per Notch Values

Notch	1	2	3	4	5	6	7	8
BSFC, gal/bhp-h	*	0.009 ± 0.003	0.010 ± 0.004	0.009 ± 0.003	0.005 ± 0.003	0.010 ± 0.007	0.004 ± 0.003	*
CO, g/bhp-h	- 0.34 ± 0.17	- 0.20 ± 0.07	- 0.36 ± 0.08	- 1.00 ± 0.19	- 1.3 ± 0.6	- 1.2 ± 0.8	- 1.2 ± 0.7	- 0.51 ± 0.08
CO_2, g/bhp-h	*	- 80 ± 20	- 90 ± 30	- 70 ± 30	- 40 ± 30	- 90 ± 60	- 30 ± 30	*
NO_X, g/bhp-h	*	- 1.0 ± 0.9	- 1.5 ± 0.8	- 0.9 ± 0.5	*	*	*	*
THC, g/bhp-h	- 0.11 ± 0.04	- 0.09 ± 0.07	*	- 0.06 ± 0.03	- 0.03 ± 0.02	- 0.06 ± 0.02	- 0.05 ± 0.02	- 0.03 ± 0.02
TPM[a], g/bhp-h	*0.07 ± 0.05*	*0.09 ± 0.04*	*0.11 ± 0.04*	*0.11 ± 0.04*	*0.13 ± 0.04*	*0.18 ± 0.07*	*0.28 ± 0.07*	*0.30 ± 0.07*

BSFC and Brake-Specific Emission Rate Change as Percentage of Baseline								
BSFC	*	13 ± 4%	15 ± 6%	13 ± 4%	8 ± 5%	15 ± 11%	7 ± 5%	*
CO	- 33 ± 17%	- 31 ± 11%	- 36 ± 9%	- 50 ± 10%	- 40 ± 20%	- 30 ± 20%	- 50 ± 30%	- 50 ± 8%
CO_2	*	- 13 ± 4%	- 15 ± 6%	- 13 ± 5%	- 8 ± 5%	- 15 ± 11%	- 6 ± 5%	*
NO_X	*	- 9 ± 7%	- 14 ± 8%	- 8 ± 5%	*	*	*	*
THC	- 32 ± 12%	- 30 ± 30%	*	- 27 ± 12%	- 13 ± 10%	- 22 ± 9%	- 22 ± 10%	- 17 ± 12%
TPM[a]	_50 ± 30%_	_60 ± 30%_	_42 ± 17%_	_42 ± 16%_	_50 ± 18%_	_70 ± 30%_	_140 ± 30%_	_170 ± 40%_

* Not statistically significant
[a]TPM results represent increased emissions as compared to baseline tests.

Duty cycle-weighted emissions result from weighting factors applied to the emissions and bhp produced during each notch. Title 40 CFR 92.132 provides the line-haul and switch duty weighting factors.

Duty Cycle-Weighted BSFC and Emission Rate Change						
Line-haul Duty Cycle						
Parameter	BSFC, gal/bhp-h	CO, g/bhp-h	CO_2, g/bhp-h	NO_X, g/bhp-h	THC, g/bhp-h	TPM[a], g/bhp-h
Delta	0.003 ± 0.002	- 0.75 ± 0.14	- 30 ± 20	*	- 0.06 ± 0.03	_0.23 ± 0.08_
Percentage of baseline	5 ± 4%	- 44 ± 8%	- 5 ± 4%	*	- 22 ± 12%	_100 ± 40%_
Switch Duty Cycle						
Delta	0.008 ± 0.003	- 0.9 ± 0.3	- 70 ± 30	- 1.2 ± 0.9	- 0.12 ± 0.8	_0.12 ± 0.04_
Percentage of baseline	10 ± 4%	- 39 ± 12%	- 10 ± 4%	- 9 ± 7%	- 27 ± 18%	_46 ± 18%_

* Not statistically significant
[a]TPM results represent increased emissions as compared to baseline tests. TPM emissions remained below the Tier 0 standards (0.60 and 0.72 g/bhp-h for line-haul and switch duty cycles, respectively) for all baseline and treated fuel test runs.

The test campaign did not quantify engine bhp at the low and high idle notches, so this report does not include those brake horsepower-specific results. The following table shows the changes in CO emissions for the idle notches. Other emissions changes were not statistically significant for the idle notches.

CO Emission Rate Change at Idle		
	Low Idle	High Idle
Delta, g/bhp-h	- 100 ± 50	- 110 ± 40
Percentage of baseline	- 34 ± 16%	- 37 ± 14%

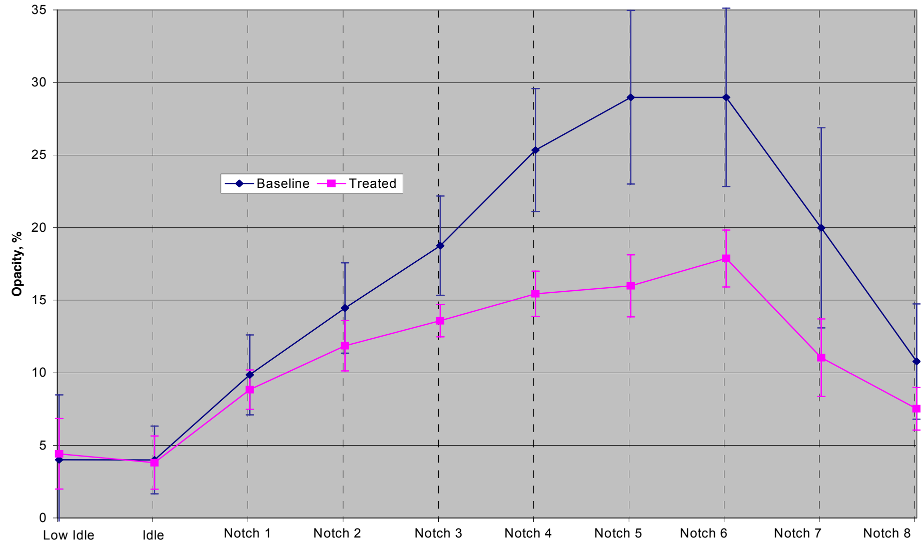
Smoke emissions (or opacity, the amount of ambient light which is blocked by the exhaust plume) generally improved over the baseline with statistically significant changes occurring for notches 3 through 7, depending on the averaging algorithm. Page S-6 presents these results as charts. The error bars on the charts represent one standard deviation at each notch.

The following table provides the compensated brake horsepower, sample standard deviation, and engine RPM seen during the tests for reference. Low and high idle RPM, which this table does not include, were 254 and approximately 320, respectively, for both fuel conditions.

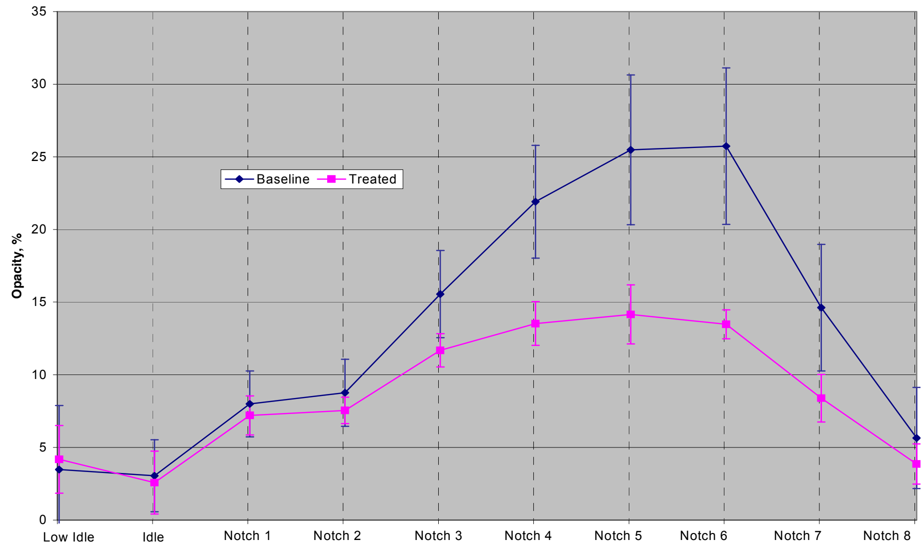
Compensated Brake Horsepower at Engine and RPM								
Notch	1	2	3	4	5	6	7	8
Baseline mean bhp	288	502	866	1157	1555	2100	2675	2962
s_{n-1}	4	4	5	6	11	200	17	14
Engine RPM	300	384	492	568	651	732	828	912
Treated fuel mean bhp	293	540	920	1226	1645	2320	2870	2905
s_{n-1}	9	20	20	15	19	40	20	5
Engine RPM	317	388	498	573	655	733	830	914

For reference, engine exhaust gas intake air temperatures were:

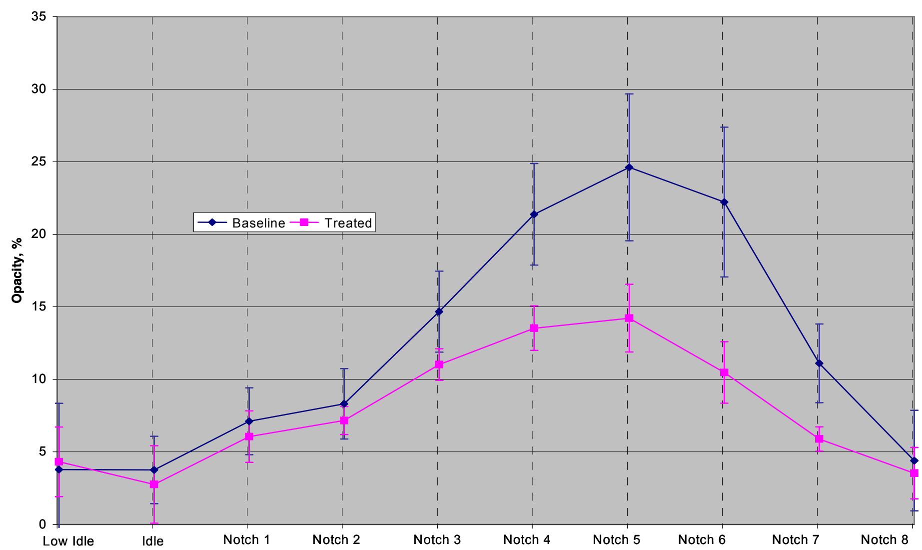
Mean Exhaust Gas and Engine Intake Air Temperatures										
Notch	Lo Idle	Hi Idle	1	2	3	4	5	6	7	8
Baseline exhaust, ^oF	223	201	297	388	489	581	669	732	718	720
s_{n-1}, ^oF	8	2	3	12	10	8	4	6	4	6
Engine intake air, ^oF	76	76	77	77	77	78	77	76	77	77
s_{n-1}, ^oF	6	5	5	9	2	2	2	2	3	4
Treated exhaust, ^oF	239	172	230	315	424	511	599	655	667	671
s_{n-1}, ^oF	32	7	26	35	32	28	29	96	92	91
Engine intake air, ^oF	49	49	49	50	52	52	55	58	60	60
s_{n-1}, ^oF	8	8	7	6	6	6	7	6	6	4



3-Second Peak Opacity



30-Second Peak Opacity



Steady-State Opacity

Duty cycle-weighted TPM emissions were below the Tier 0 emission standards for both fuel conditions. The verification results, however, indicated that TPM emissions increased while the locomotive was operating on the treated fuel as compared to baseline emissions. This occurred even though all the gaseous and visible emissions (smoke opacity) decreased significantly.

In an effort to explain the significant TPM emissions increases while observing reductions in all other emissions, the GHG Center investigated possible effects of the locomotive particulate sampling system. Also, EnviroFuels and the GHG Center hypothesized that knowledge of the particulate composition or morphology may help explain the causes of the reported increase. Independent laboratories performed scanning electron microscopy with energy dispersive X-ray spectroscopy, X-ray photo electron spectrometry, and SW-846 Method 8270 analyses on selected particulate filters about 4 months after the end of field tests. The GHG Center considers the TPM test results to be valid, but the post-test investigations into the reasons for the increases were inconclusive.

The peer-reviewed *Test and Quality Assurance Plan—EnviroFuels Diesel Fuel catalyzer Fuel Additive* contains detailed discussion of the verification test design, measurement procedures, quality assurance and quality control methods. It and the associated Verification Report are available from the GHG Center's Internet site at www.sri-rtp.com or the ETV Program site at www.epa.gov/etv.

Signed by Sally Gutierrez (8/26/2005)

Sally Gutierrez
Director
National Risk Management Research Laboratory
Office of Research and Development

Signed by Tim Hansen (8/26/2005)

Timothy A. Hansen
Director
Greenhouse Gas Technology Center
Southern Research Institute