

**Preliminary Evaluation of Biofriendly Green Plus®
Additive**

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Executive Summary

A preliminary assessment of the Biofriendly Green Plus® additive was conducted by evaluating its impact on engine condition before and after mileage accumulation on the additive. Biofriendly utilized a Motorhome for the evaluation. Comparisons were made between the baseline condition of the engine with CARB diesel fuel and after adding the Biofriendly Green Plus® additive into CARB diesel fuel and operating the vehicle for 6,200 miles. The engine condition was evaluated by removing the cylinder head and taking pictures of the valves, cylinder heads, piston heads, valve stems, and fuel injectors.

The results of this study are summarized below.

- A noticeable cleaning effect was found in comparing picture of the engine disassembled before and after the mileage accumulation. This cleaning is most readily seen for the valves, where there is a considerable reduction in the build of black carbon on the heads after the conclusion of the mileage accumulation.
- There was also a reduction in the amount of the black carbon build up on the piston heads, although this is a bit difficult to see simply from pictures. This reduction in black carbon buildup was primarily seen in the groove on the piston head.
- The valve stems and fuel injectors did not show a significant cleaning affect.

1 Introduction

A preliminary assessment of the Biofriendly Green Plus® additive was conducted by evaluating its impact on engine condition before and after mileage accumulation on the additive. Biofriendly utilized a Motorhome for the evaluation. Comparisons were made between the baseline condition of the engine with CARB diesel fuel and after adding the Biofriendly Green Plus® additive into CARB diesel fuel and operating the vehicle for 6,200 miles. The engine condition was evaluated by removing the cylinder head and taking pictures of the valves, cylinder heads, piston heads, valve stems, and fuel injectors.

2 Experimental Procedures

A motorhome with a Caterpillar (CAT) engine was used as the test engine. This motorhome was powered with a California Air Resources Board (CARB) diesel fuel with and without the Biofriendly Green Plus® additive. A description of the engine and the test vehicle is provided in Table 2-1. Picture of the motorhome is provided in Figure 2-1. The emission control systems include direct fuel injection and a turbocharger with a charge air cooler. The certification Executive Order for the engine tested are provided in Appendix A.

Table 2-1. Engine and vehicle Specifications

Engine	Manufacturer	Engine Model	Model Year	Engine Family	Engine Type	Horse power	Displacement	Peak Torque
	CAT	3126	2002	2CPXH0442HBX	Compression-ignition	330 HP	7.2 L	330 HP @ 2400 rpm
Vehicle	Manufacturer	Vehicle Year	VIN number		Empty Weight	Mileage	License Plate #	
	Horizon	2003	4UZA AHAK23CK83287		27,910 lbs	28,425 miles	6ULN282	

The engine condition was evaluated in the baseline condition and after mileage accumulation with the Biofriendly Green Plus® additive. The baseline condition of the engine was assessed at a vehicle mileage of 28,425. The baseline condition was evaluated after approximately 3600 miles of operation with the baseline CARB diesel fuel. The final condition of the engine after operation with the Biofriendly additive was assessed at a vehicle mileage of 34,610. Thus, the vehicle was driven for approximately 5,700 miles with the Biofriendly additive to evaluate the cleaning effect of operating with the Biofriendly Green Plus® additive.

Diagnostic evaluations were conducted at Johnson Machinery before and after the mileage accumulation. The vehicle was initially evaluated by Johnson Machinery to ensure the vehicle was in good operating condition. Some repairs conducted prior to the mileage accumulation including a realignment. Once it was decided that the engine and chassis were in good operating condition, the engine was disassembled to allow pictures to be taken of the engine in its baseline condition. Following the mileage accumulation, some additional repairs were conducted. In particular, the turbocharger was checked and cleaned to insure it was in proper work order. Following the completion of these checks, the engine was again disassembled to allow pictures to be taken of the engine in its condition after running the Biofriendly Green Plus® additive.

A horsepower test was also run on the Johnson Machinery repair grade heavy-duty chassis dynamometer for the baseline condition and the condition following the mileage accumulation with the Biofriendly Green Plus® additive.



Figure 2-1. Picture of the Motorhome.

3 Pre- and Post-Engine Evaluation

One of the most critical elements of this study was to evaluate the condition of the engine from the baseline condition before the addition of the Biofriendly Green Plus® additive to after the mileage accumulation of 6,200 miles using the Biofriendly Green Plus® additive. This evaluation included the disassembly of the engine and visual and photographic inspection of the cylinders, pistons, valves and fuel injectors. Additionally, horsepower tests were run on a chassis dynamometer to evaluate any changes in horsepower than might have occurred over the course of the study.

3.1 Engine Condition

The engine was disassembled before and after the mileage accumulation with the Biofriendly additive. Figure 3-1 to Figure 3-4 show pictures of the intake and exhaust valves, combustion cylinders and piston heads, fuel injectors, and valve stems, respectively. To allow for a better comparison of the condition of the engine before and after the mileage accumulation, the before and after pictures are presented side by side. Overall, the pictures show a noticeable cleaning effect between the before and after mileage accumulation photographs. This cleaning is most readily seen in the pictures of valves in Figure 3-1, where there is a considerable reduction in the build of black carbon on the heads after the conclusion of the mileage accumulation. There was also a reduction in the amount of the black carbon build up on the piston heads, although this is a bit difficult to see simply from pictures. This reduction in black carbon buildup was primarily seen in the groove on the piston head. For the valve stems, there was not a significant reduction of black carbon, although some valve did appear to also show a reduction in the black carbon build up. The fuel injectors did not show a dramatic reduction in black carbon between the before and after pictures. It should be noted that the reduction in black carbon was also noted by one of the main technicians

servicing the engine. He noted that the change in the engine condition and the observed cleaning was significant, and that the condition of the engine appeared to be consistent with hotter combustion.



Figure 3-1. Before and After Pictures of Intake and Exhaust Valves.



Figure 3-2. Before and After Pictures of Cylinder and Piston Head.



Figure 3-3. Before and After Pictures of Fuel Injectors.



Figure 3-4. Before and After Pictures of Valve Stems.

3.2 Horsepower Results

Horsepower tests were conducted before and after the mileage accumulation with the Biofriendly Green Plus additive. These horsepower curves were run on the repair grade dynamometer at Johnson Machinery. Horsepower curves from before mileage accumulation are shown in Figure 3-5 and Figure 3-6. The horsepower curve for the after mileage accumulation is shown in Figure 3-7.

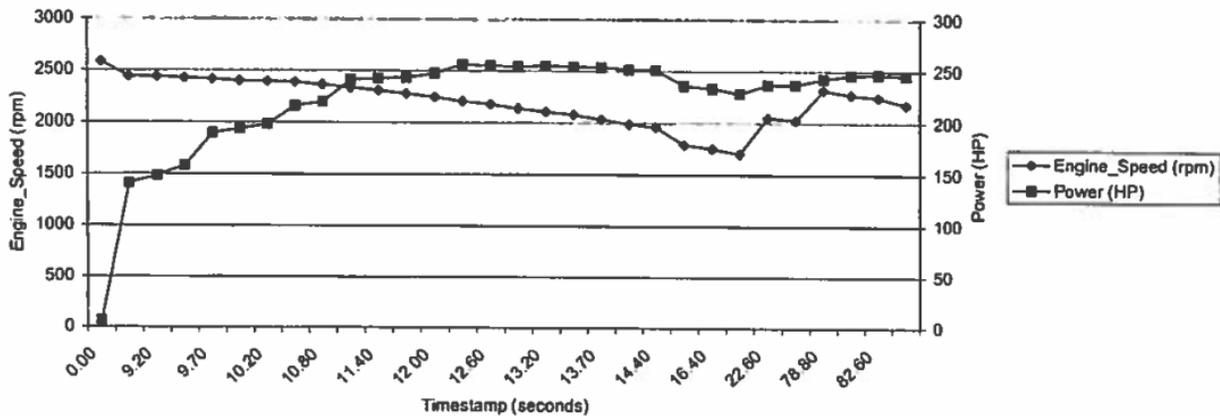


Figure 3-5. Before Mileage Accumulation Horsepower Test Results

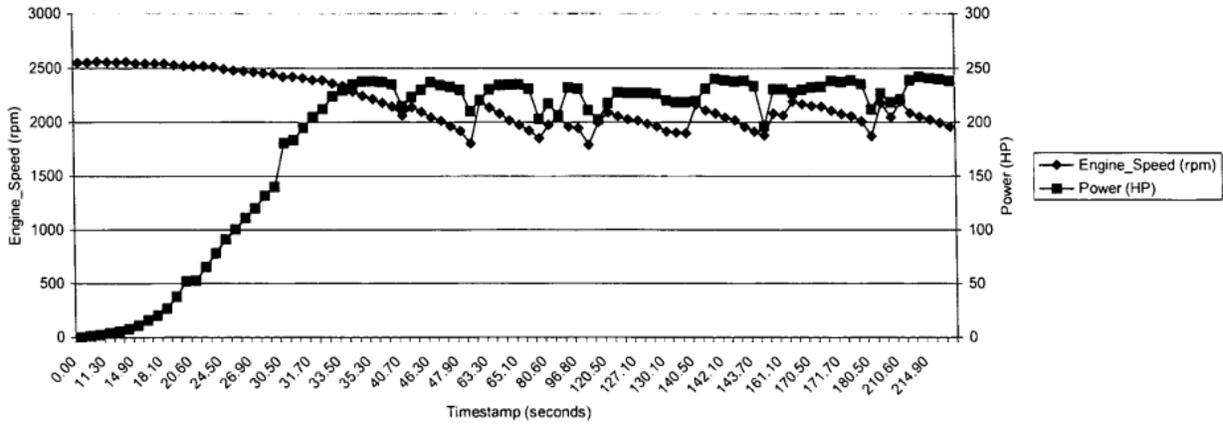


Figure 3-6. Before Mileage Accumulation Horsepower Test Results #2

Figure 3-7. After Mileage Accumulation Horsepower Test Results

4 Summary

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Appendix

Appendix A: Executive Order for Test Engine

 AIR RESOURCES BOARD	CATERPILLAR INC.	EXECUTIVE ORDER A-013-0146 New On-Road Heavy-Duty Engines
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Pursuant to the authority vested in the Air Resources Board by Health and Safety Code (HSC) Division 26, Part 5, Chapter 2; and pursuant to the authority vested in the undersigned by HSC Sections 39515 and 39516 and Executive Order G-45-9; and

Pursuant to the December 15, 1998 Settlement Agreement between the Air Resources Board and the manufacturer, and any modifications thereof to the Settlement Agreement;

IT IS ORDERED AND RESOLVED: That the following engine and emission control systems produced by the manufacturer are certified as described below for use in on-road motor vehicles with a manufacturer's gross vehicle weight rating (GVWR) over 14,000 pounds. Production engines shall be in all material respects the same as those for which certification is granted.

MODEL YEAR	ENGINE FAMILY	ENGINE SIZE (liter)	FUEL TYPE	STANDARDS & TEST PROCEDURE	INTENDED SERVICE CLASS
2002	2CPXH0442HBX	7.2	Diesel	Diesel	Medium-Heavy-Duty
SPECIAL FEATURES & EMISSION CONTROL SYSTEMS			ENGINE MODELS / CODES (rated power in horsepower, hp)		
DDI, TC, CAC, ECM, OC			See Attachment		
<small> ABBREVIATIONS: OC=oxidizing catalyst YWC=three-way catalyst WU (prefix) =warm-up catalyst O2S=oxygen sensor HO2S=heated O2S TBI=throttle body fuel injection MPI=multiport fuel injection SPI=squential MPI DDID=direct indirect diesel injection TDSC=turbo/super charger CAC=charge air cooler EGR=exhaust gas recirculation AIR=secondary air injection PAIR=pulsed AIR SP=smoke puff limiter ECM/PCM=engine/powertrain control module EM=engine modification 2 (prefix)parallel (2) (suffix)in series </small>					

The following are the exhaust emission standards (STD), or family emission limit(s) (FEL) as applicable, and certification levels (CERT) for this engine family for hydrocarbons (HC) or non-methane hydrocarbons (NMHC), oxides of nitrogen (NOx), or NMHC+NOx, carbon monoxide (CO), particulate matter (PM), and formaldehyde (HCHO) in grams per brake horsepower-hour (g/bhp-hr) under the "Federal Test Procedure" (FTP) (Title 13, California Code of Regulations, (13 CCR) Section 1956.1 (urban bus) or 1956.8 (other than urban bus)), and under the "Euro III Test Procedure" (EURO) in the Settlement Agreement, including a EURO's "Not-to-Exceed" NOx standard: (The emission standards and certification levels for default operations permitted under 13 CCR Section 1956.1 or 1956.8 are in parentheses.)

* = not applicable	HC		NMHC		NOx		NMHC+NOx		EURO'S NOT-TO-EXCEED NOx STD		PM		HCHO	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
(DIRECT) STD	1.3	1.3	*	*	*	*	*	*	15.5	15.5	0.10	0.10	*	*
AVERAGE STD	*	*	*	*	4.0	4.0	*	*	*	*	*	*	*	*
FEL	*	*	*	*	3.5	3.5	*	*	*	*	*	*	*	*
CERT	0.3	0.1	*	*	3.1	3.1	*	*	1.2	0.3	0.09	0.06	*	*

BE IT FURTHER RESOLVED: That certification to the FEL(s) listed above, as applicable, is subject to the following terms, limitations and conditions. The FEL(s) is the emission level declared by the manufacturer and serves in lieu of an emission standard for certification purposes in any averaging, banking, or trading (ABT) programs. It will be used for determining compliance of any engine in this family and compliance with such ABT programs.

BE IT FURTHER RESOLVED: That for the listed engine models, the manufacturer has submitted the materials to demonstrate certification compliance with 13 CCR Sections 1965 (emission control labeling), and 2035 et seq. (emission control system warranty).

BE IT FURTHER RESOLVED: That the listed engine models are conditionally certified subject to the following conditions: (1) The Settlement Agreement is in effect; and, (2) The manufacturer is in compliance with all applicable certification requirements of the Settlement Agreement and any modifications thereof.

Engines certified under this Executive Order shall conform to all applicable California emission regulations and all requirements under the Settlement Agreement and any modifications thereof.

The Bureau of Automotive Repair will be notified by copy of this Executive Order.

This Executive Order is not valid for engines produced on or after October 1, 2002.

Executed at El Monte, California on this 20th day of December 2001.


 R. B. Summerfield, Chief
 Mobile-Source Operations Division