CTM-UFMG
CENTRO DE TECNOLOGIA DA MOBILIDADE

TEST REPORT

EVALUATION OF THE ADOPTION OF THE GREEN PLUS CATALYST IN THE PERFORMANCE, FUEL CONSUMPTION AND POLLUTANT EMISSIONS OF A DIESEL ENGINE ON A BENCH DYNAMOMETER

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1 - INTRODUCTION

This test report presents the results of the evaluation of the adoption of the *Green Plus* catalyst in the performance, fuel consumption and pollutant emissions of a diesel engine on a dynamometer bench performed by the technical team of CTM/UFMG for the company Horeb Brasil (CNPJ (ENI) 35.064.391/0001-92), upon service request. The methodology used and the results obtained during the experimental evaluation are described in this document. Initially,the original compression ignition engine used in the tests was characterized according to Phase III of ABNT Standard NBR 16721 of 2018, fueled with common diesel (S500) purchased in the metropolitan region of Belo Horizonte/MG. Subsequently, the fuel used in the tests was catalyzed with the addition of *Green Plus*, provided by the contracting party and in the concentration of fifty parts per million (50 PPM), this being the only modification performed throughout the presented test. Subsequently, the engine used in the tests was conditioned for 120 hours of dynamometer test, according to a mixed cycle of use with variable rotation and load. At every 20 hours of test, performance and fuel consumption data at full load were measured and stored. Once the 120 hours of conditioning were completed, the engine underwent a new characterization stage according to Phase III of ABNT Standard NBR 16721 of 2018. Thus, it was possible to make a comparative analysis about the influence of said catalyst in theoperation of the engine under study, as well as a verification of the influence of the continuous use of *Green Plus*. The details of the procedures and the results obtained in each step are described in this work.

2 - METHODOLOGY

The experimental methodology was executed in the dependencies of the Mobility Technology Center - CTM/UFMG. Its steps are detailed in the sequence of the text, according to the chronological sequence of its realization. The activities started with the selection of the test object, being chosen the NEF 4 engine, manufactured by IVECO, 4.5 liters, 4 cylinders, 4 strokes, supercharged (turbocharged) with direct injection of diesel, using Delphi mechanical injection system, applied in backhoe loaders model B95B of New Holland. According to the manufacturer, this engine develops a net power of 75.3 kW at 2200 rpm and a net torque of 398 N.m at 1400 rpm (SAEJ1995). This engine was provided by the engine testing laboratory of CTM/UFMG, as well as all accessories needed for its operation.

Then, the test room was prepared and the fuel feeding system was adapted (introduction of polypropylene lines and metal drum with fixed lid with two mouths, with 50 liters of volumetric capacity and internal epoxy painting) for storage and conduction of diesel to which the *Green Plus* catalyst was added. This intervention was necessary to meet Horeb Brasil's recommendation that the product tested should not remain in contact with components made of stainless steel.

After the modifications in the test room, the engine was installed in the bench dynamometer of the CTM/UFMG laboratory. At this stage, in addition to the assembly of the mechanical components, all the necessary instrumentation was installed in the test room to perform the tests, in accordance with the requirements of ABNT NBR 17621:2018 and ABNT NBR ISO 1585:1996 standards.

The first phase of the tests consisted in characterizing the engine in its original configuration and using common diesel (S500) without the addition of *Green Plus* as fuel. The goal was to create a reference of the engine behavior (*baseline*) used in a comparative manner in all tests. In this phase, the engine went through a run-in and running-in cycle recommended by the manufacturer, aiming to ensure the declared performance. The conditions tested were:

Rotation: 850 rpm (idle), 1200 rpm, 1400 rpm, 1600 rpm, 1800 rpm, 2200 rpm.

Torque: 100% (full load), 75%, 50% and 25% of maximum torque.

At all operating points exposed above, the power, torque and fuel consumption data were obtained. As for the exhaust gas pollutant emissions were measured at specific and more relevant points in vehicle driving cycles, as follows: 850 rpm (idle speed), 1400 rpm (maximum torque rotation), 2200 rpm (maximum power rotation), in stabilized operation conditions.

After performing the first stage of tests, the *Green Plus* catalyst provided by the contracting party was added to the common diesel (S500) in the concentration of fifty parts per million (50 PPM), without physical changes in any component of the engine used. According to Horeb Brasil's recommendation, the CTM technical team performed the engine conditioning, using the common diesel (S500) catalyzed with the addition of *Green Plus* during 120 hours of test. The programming of an automatic cycle was performed

in the dynamometer *software*, establishing dynamic operating points for the engine in order to submit it to mixed load and rotation conditions, referring to urban and highway vehicle driving cycles. This step was essential to ensure the representativeness of the test methodology adopted for the engine, which in itself allows a flexibility of applications, such as public transport (buses, vans) and cargo (trucks, pickups, off-road vehicles). Figures 1 and 2 present the configurations of the cycle programmed by the technical team of CTM/UFMG.

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	Step Name	Step Time	Engine DynoEngine/Dyno Control						
Step Number	name	[s]	Command	Throttle Demand [%]	Throttle Ramp Time ...	Speed Demand [r...	Speed Ramp Time [s]	Torque Demand [N...	Torque Ramp Time ...
1	Idle1	180	Mode Idle						
2	WOT2	60	Mode Thro...	100	5	1200	10		
3	WOT3	120	Mode Thro...	100	0	1400	5		
4	PLoad4	300	Mode Torq...			1400	5	290	5
5	PLoad5	300	Mode Torq...			1400	5	200	5
6	PLoad6	60	Mode Torq...			1600	5	285	5
7	PLoad7	60	Mode Torq...			1800	5	275	5
8	WOT8	60	Mode Thro...	100	5	2000	10		
9	WOT9	180	Mode Thro...	100	5	2200	5		
10	PLoad10	180	Mode Torq...			2200	5	220	5
11	PLoad11	120	Mode Torq...			2000	5	170	5
12	PLoad12	120	Mode Torq...			1800	5	180	5
13	PLoad13	60	Mode Torq...			1600	5	190	5
14	PLoad14	300	Mode Torq...			1400	5	190	5
15	Pload15	240	Mode Torq...			1400	5	100	5
16	PLoad16	300	Mode Torq...			1400	5	190	5
17	PLoad17	120	Mode Torq...			1400	5	300	5
18	WOT18	120	Mode Thro...	100	5	1400	10		
19	PLoad19	120	Mode Torq...			1400	5	300	5
20	PLoad20	60	Mode Torq...			1400	5	190	5
21	PLoad21	60	Mode Torq...			1200	5	190	5
22	PLoad22	420	Mode Torq...			1200	5	100	5
23	Idle23	120	Mode Idle						
24	Done								

Figure 1. Automatic engine conditioning cycle programming on bench dynamometer.

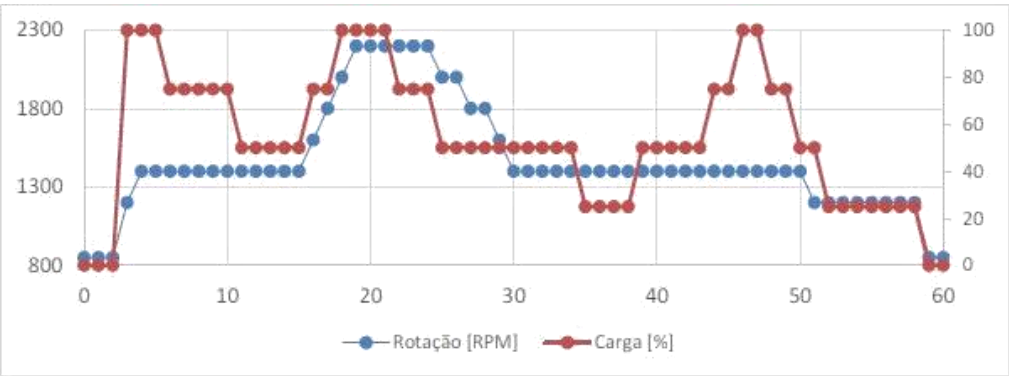

Figure 2. Engine operating points in mixed cycle.

Every 20 hours of operation in the cycle, the performance curve was measured at full load, with the acquisition of data relating to power, torque, specific fuel consumption (at all points of operation) and pollutant emissions (at idle speed, 1400 rpm and 2200 rpm). Thus, the characteristic curves with the engine using the common diesel (*baseline*) and with the common diesel catalyzed with *Green Plus* after 20, 40, 60, 80, 100 and 120 hours of tests were raised, in order to verify the evolution of the fuel conditioning process provided by the catalyst under study. With 120 hours of cycle elapsed, the final performance curves were raised, analogous to that performed in the initial characterization of the original engine (now with the addition of *Green Plus*), according to the conditions shown below:

Rotation: idle, 1200 rpm, 1400 rpm, 1600 rpm, 1800 rpm, 2200 rpm. Torque: 100% (maximum torque, or full load), 75%, 50% and 25% of maximum torque.

Again, pollutant emissions were measured at idle speed, 1400 rpm (maximum torque) and 2200 rpm (maximum power). A history of the engine conditioning tests can be seen in Table 1. Once the experimental tests were completed, the data acquired in all tests were treated, which enabled the subsequent preparation of graphs and results, shown in the sequence of the document.

Table 1. Sequence adopted for engine conditioning in 120 hours of testing.

Motor conditioning NEF 4				
Day	**H.initial**	**H. final**	**N. cycles completed**	**Hours Spent**
July 29th, 2020	508.2	517.8	8	9.6
July 30th, 2020	518.1	528.6	10	10.5
July 31st 2020	528.8	541.8	10	13.0
Aug. 08th 2020	543.2	553.3	9	10.1
Aug. 09th 2020	553.5	563.1	8	9.6
Aug. 10th 2020	563.1	573.1	8	10.0
Aug. 11th 2020	573.1	586.7	11	13.6
Aug. 12th 2020	586.8	590.4	3	3.6
Aug. 13th 2020	590.4	594.7	2	4.3
Oct. 09th 2020	596.3	599.8	3	3.5
Oct. 13th 2020	600	608.5	8	8.5
Oct. 14th 2020	608.5	614.1	5	5.6
Oct. 15th 2020	614.1	627.0	9	12.9
Oct. 16th 2020	627	633.9	0	6.9
		TOTAL	**94**	**121.7**

3- RESULTS

Figure 3 shows the corrected power curves as a function of rotation for the tests that range from the engine using regular diesel (*Baseline*) to the final tests of the engine using the regular diesel catalyzed with *Green Plus (GP)*. Figure 4 shows the behavior of specific fuel consumption as a function of engine speed for the tests that range from the supply with regular diesel (*Baseline*) to the final tests of the engine with common diesel catalyzed (*GP*).

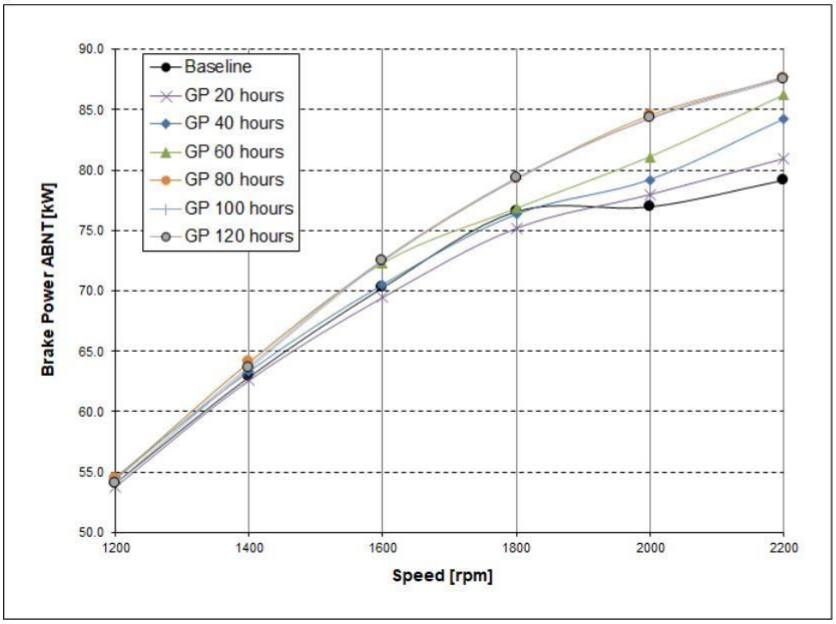

Figure 3. Corrected engine power behavior as a function of RPM at full load during the 120 hours of testing with the *Green Plus* catalyst.

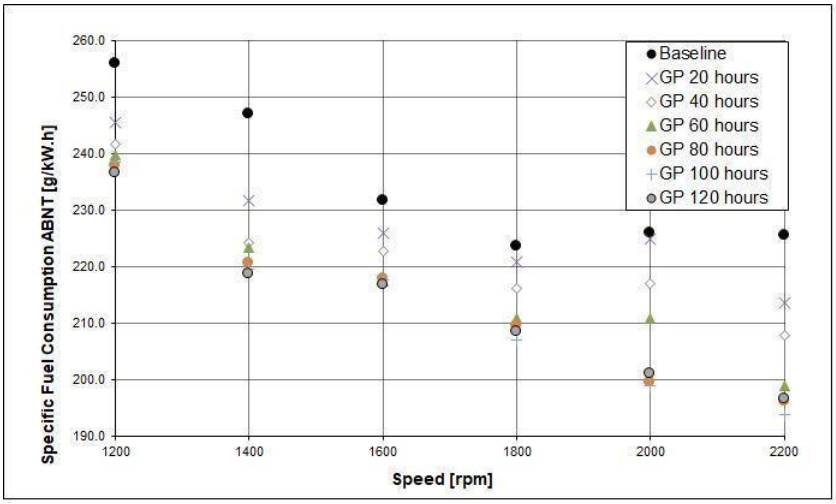

Figure 4. Behavior of the specific fuel consumption of the engine as a function of speed, at full load, during the 120 hours of testing with the *Green Plus*.

Figures 5, 6 and 7 present the results obtained for corrected power, specific fuel consumption and fuel conversion efficiency as a function of rotation for the tests at full load with the engine supplied with common diesel (*baseline*) and with catalyzed common diesel after 120 hours of operation (*GP 120 hours*). The percentage differences obtained in each measured parameter compared to the baseline value are plotted.

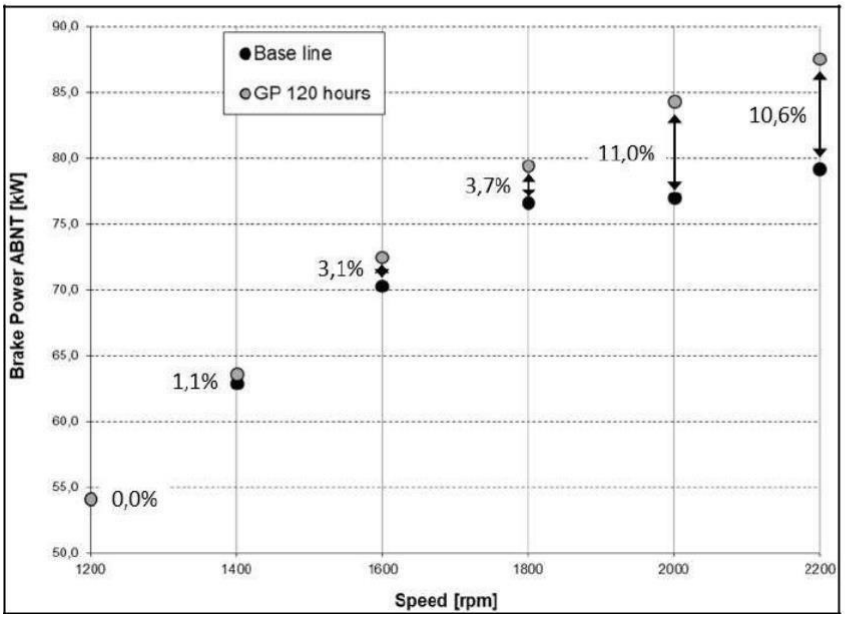

Figure 5. Comparison between the corrected power produced by the engine as a function of RPM, at full load, during the 120 hours of testing with the *Green Plus*.

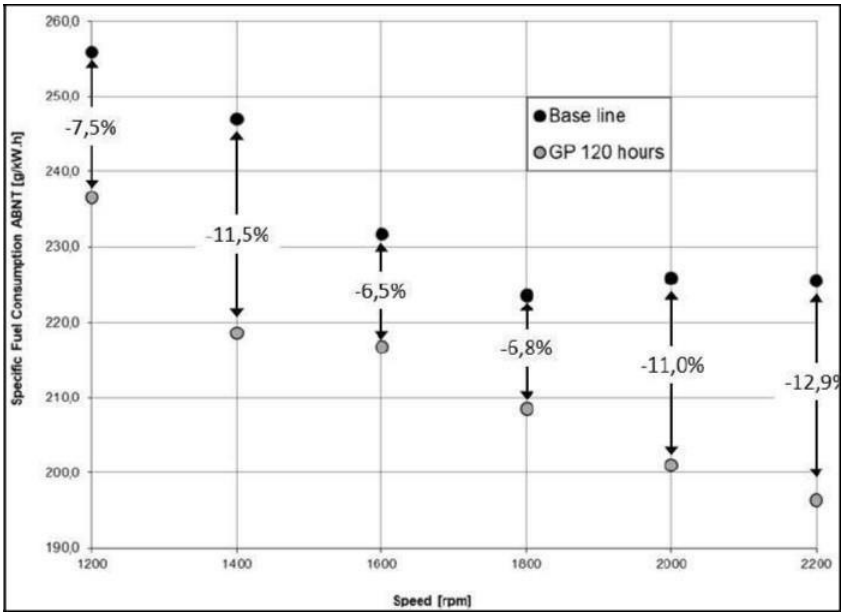

Figure 6. Comparison of engine specific fuel consumption as a function of RPM and at full load during the 120 hours of testing with *Green Plus*.

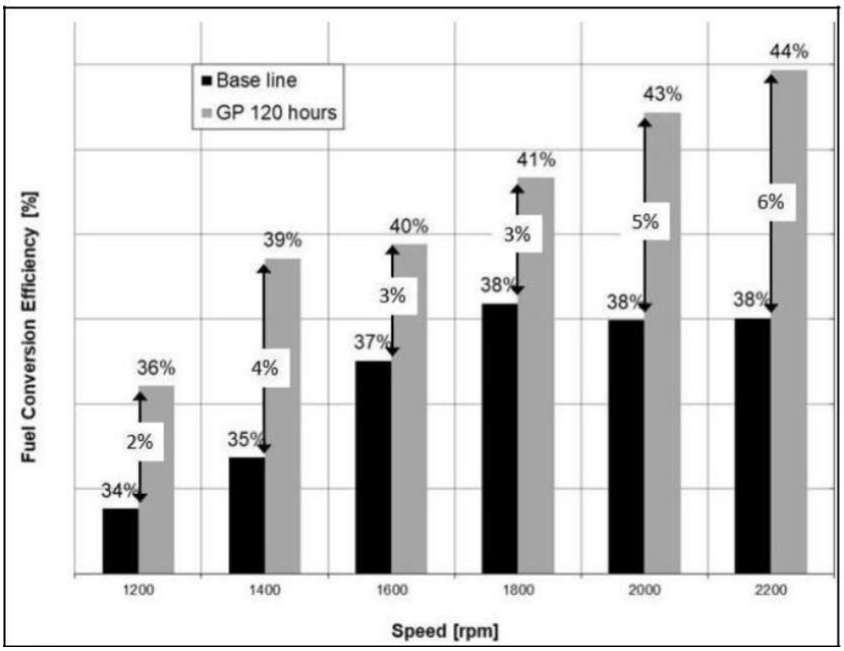

Figure 7. Comparison of engine fuel conversion efficiency as a function of RPM, at full load, during the 120 hours of testing with *Green Plus*.

Regarding the emissions of pollutants by exhaustion, the verification and treatment of the determined data was the responsibility of Horeb Brasil, according to the agreement between the contracting and executing institutions of the project.

4 - FINAL CONSIDERATIONS

The test methodology and results presented in this report show that the addition of the *Green Plus* catalyst to the NEF4 diesel engine, after 120 hours of conditioning and operation on a bench dynamometer, provided improvements in performance with up to a 10.6% increase in the power developed by the engine and a reduction in specific fuel consumption of up to 12.9%.