CTM-UFMG
CENTRO DE TECNOLOGIA DA MOBILIDADE

TEST REPORT

EVALUATION OF THE ADOPTION OF *GREEN PLUS* CATALYST IN THE PERFORMANCE AND FUEL CONSUMPTION OF A FLEX-FUEL ENGINE FUELED WITH REGULAR GASOLINE IN BENCH DYNAMOMETER

José Guilherme Coelho Baêta, Dr.
Department of Mechanical Engineering - UFMG
Coordinator of the Center for Mobility Technology - CTM

Fabrício José Pacheco Pujatti, Dr.
Department of Mechanical Engineering - UFMG
Researcher at the Center for Mobility Technology - CTM

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Escola de Engenharia da UFMG
Departamento de Engenharia Mecânica
Av. Antônio Carlos, 6627 – Pampulha CEP: 31.270-901
Belo Horizonte/MG

1 - INTRODUCTION

This test report presents the results of the evaluation of the adoption of the *Green Plus* catalyst on the performance and fuel consumption of a *flex-fuel* engine on a dynamometer bench carried out by the technical team of the CTM/UFMG for the company Horeb Mercosul through a service provision request. This report presents the methodology used and the results obtained during this evaluation. Initially, the spark ignition engine used in the tests was characterized according to ABNT NBR ISO 1585 of 1996, fuelled with regular gasoline (E27) supplied by the contracting party. Subsequently, the fuel used in the tests was catalyzed with the addition of *Green Plus* at a concentration of 50 PPM, as recommended by the manufacturer of the product (Horeb Brazil), this being the only change made throughout the test presented in this report. Then, 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. During these 120 hours of conditioning the performance and fuel consumption data at full load were monitored, and these parameters were measured and stored every 20 hours of testing. At the end of the conditioning period, the engine went through a new stage of characterization according to the ABNT NBR ISO 1585 Standard of 1996. Thus, it was possible to make a comparative analysis about the influence of the catalyst in the operation of the engine under study, as well as a verification of the influence through the continuous use of *Green Plus* in the engine.

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 realization. The activities started with the selection of the test object, being chosen the Sigma engine, manufactured by Ford, 1.596 liters, 4 cylinders, 4 stroke, naturally aspirated, with multipoint indirect fuel injection (PFI), static ignition with lost spark, electronically controlled by a reprogrammable electronic management system MoTeC M800. According to the manufacturer, this engine develops an ABNT net power output of 110 hp at 6250 rpm (gasoline) and 115 hp at 5500 rpm (ethanol) and an ABNT net torque of 15.8 kgf.m at 4250 rpm (gasoline) and 16.2 kgf.m at 4250 rpm (ethanol). This engine was made available by the technical team of CTM/UFMG, as well as all accessories required for its operation.

Then, the test room was prepared and modified, where the fuel feeding system was adapted (introduction of polypropylene lines) for storing and conducting samples of regular gasoline and gasoline catalyzed with *Green Plus*. This intervention was necessary to meet the recommendation of Horeb Mercosul that the product tested should not remain in contact with components made of stainless steel.

After the modifications in the test room, the engine installation was performed in the bench dynamometer of the CTM-UFMG laboratory. In this installation stage, in addition to the assembly of the mechanical components, all the necessary instrumentation was performed in the test room, in accordance with the requirements of the ABNT NBR ISO 1585:1996 Standards, which enabled the reading of the information acquired during the tests.

The first phase of the tests consisted in verifying the electronic engine control strategies, since it was adopted a reprogrammable electronic management system (MoTeC M800). Next, the engine went through a run-in and running-in cycle recommended by the manufacturer, aiming to ensure the full achievement of its operating condition and, then, it was characterized in original configuration and using regular gasoline (E27) as fuel without the addition of *Green Plus*. The objective of this phase was to create a reference of the engine behavior (*baseline*) used in a comparative manner in all tests. The conditions tested were:

- Rotation: from 1500 rpm to 5750 rpm, with an increment of 250 rpm.
- Load: 100% (full load) and 50% of maximum torque (part load).

In all the operation points exposed above there was the measurement of power, torque and fuel consumption. The pollutant emissions were measured by Horeb Brasil's team in specific conditions, being the data obtained treated and evaluated by that company and in stabilized operation conditions (*steady state*). The conditions in which the pollutant emissions were measured were:

- Speed: 850 rpm (idle), 4250 rpm and 5500 rpm (100% and 50% load).

After the characterization of the first phase, the engine under test remained with the same initial characteristics, but began to be fueled with regular gasoline added to the *Green Plus* catalyst (E27 GP).

Following the recommendation of Horeb Mercosul, the CTM technical team performed engine conditioning, using regular gasoline added to *Green Plus* catalyst (E27 GP) during 120 hours of testing, according to an automatic operation cycle in the dynamometer control *software*. This cycle simulates, at different rotation and load points, the operating situations of an engine in urban and highway driving cycles. The objective of this phase was to measure the influence of the *Green Plus* through its continuous use in this engine.

Every 20 hours of operation in the cycle, the performance curve at full load was measured, with the acquisition of data related to power, torque and fuel consumption in the operating conditions previously described.

Thus, the characteristic curves were obtained with the engine using regular gasoline (E27), as well as using the regular gasoline added to the *Green Plus* catalyst after 20 hours (E27 GP 20h), 40 hours (E27 GP 40h), 60 hours (E27 GP 60h), 80 hours (E27 GP 80h), 100 hours (E27 GP 100h) and 120 hours (E27 GP 120h) of testing, with the objective of verifying 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 again, analogously to the initial characterization of the original engine (this time with the addition of the *Green Plus* catalyst), according to the conditions shown below:

- Rotation: from 1500 rpm to 5750 rpm, with an increment of 250 rpm.
- Load: 100% (full load) and 50% of maximum torque (part load).

In all operating points exposed above there was again the measurement of power, torque and fuel consumption. The pollutant emissions were measured again by the Horeb Brasil team in specific conditions, being the data obtained treated and evaluated by that company and in stabilized operation conditions (*steady state*). The conditions in which the pollutant emissions were measured were:

- Speed: 850 rpm (idle), 4250 rpm and 5500 rpm (100% and 50% load).

Once the experimental tests were completed, the data acquired in all tests were treated, which enabled the subsequent preparation of graphs and results, which are presented below.

3 - RESULTS

The Methodology presented above detailed the conditions for tests with the engine on the bench, with the rotation range being between 1500 rpm and 5750 rpm, with an increment of 250 rpm and in the loading conditions of 100% (full load) and 50% of the maximum torque (partial load). The identification of the samples, presented in the following results, were based on the definitions described in the Methodology.

3.1. Full Load Testing (100%)

Table 1 presents the ABNT Corrected Net Power values as a function of rotation for the tests that range from the engine supplied with regular gasoline (*baseline*) to the final tests of the engine supplied with regular gasoline added to the *Green Plus* catalyst. Figure 1 presents the respective data graphically.

Table 1. Corrected power produced by the engine as a function of rotation at full load, fueled with regular gasoline (E27) during the 120 hours of test with the use of *Green Plus* catalyst (E27 GP). Uncertainty of measurement: ±0.5 kW.

Rotation [rpm]	ABNT Net Power [kW]						
	E27	E27 GP 20h	E27 GP 40h	E27 GP 60h	E27 GP 80h	E27 GP 100h	E27 GP 120h
1500	21,1	21,2	21,3	21,4	21,3	21,3	21,5
1750	24,8	24,8	24,9	25,0	24,9	24,9	25,2
2000	29,1	29,3	29,4	29,4	29,4	29,5	29,7
2250	33,5	33,8	34,0	34,1	34,0	34,2	34,3
2500	37,2	37,5	37,7	37,7	37,7	37,7	38,1
2750	42,2	43,0	43,1	43,2	43,2	43,6	43,6
3000	45,1	45,5	45,7	45,8	45,8	46,0	46,4
3250	49,1	49,8	50,1	50,2	50,3	50,8	50,6
3500	55,0	53,3	54,9	54,7	55,0	55,4	55,6
3750	57,6	58,3	58,5	58,6	58,7	59,0	59,0
4000	63,2	63,8	64,0	64,2	64,4	64,6	64,2
4250	69,2	68,8	68,5	68,7	69,0	69,0	69,9
4500	72,4	71,7	71,7	71,8	72,1	72,4	72,9
4750	76,3	76,2	76,3	76,2	76,6	76,9	77,3
5000	79,5	79,6	79,3	79,0	79,8	79,9	80,1
5250	82,3	81,4	81,4	81,2	81,5	81,5	82,3
5500	82,6	81,3	81,0	80,8	80,6	80,8	81,5
5750	80,8	81,3	81,6	81,3	81,5	80,7	81,0

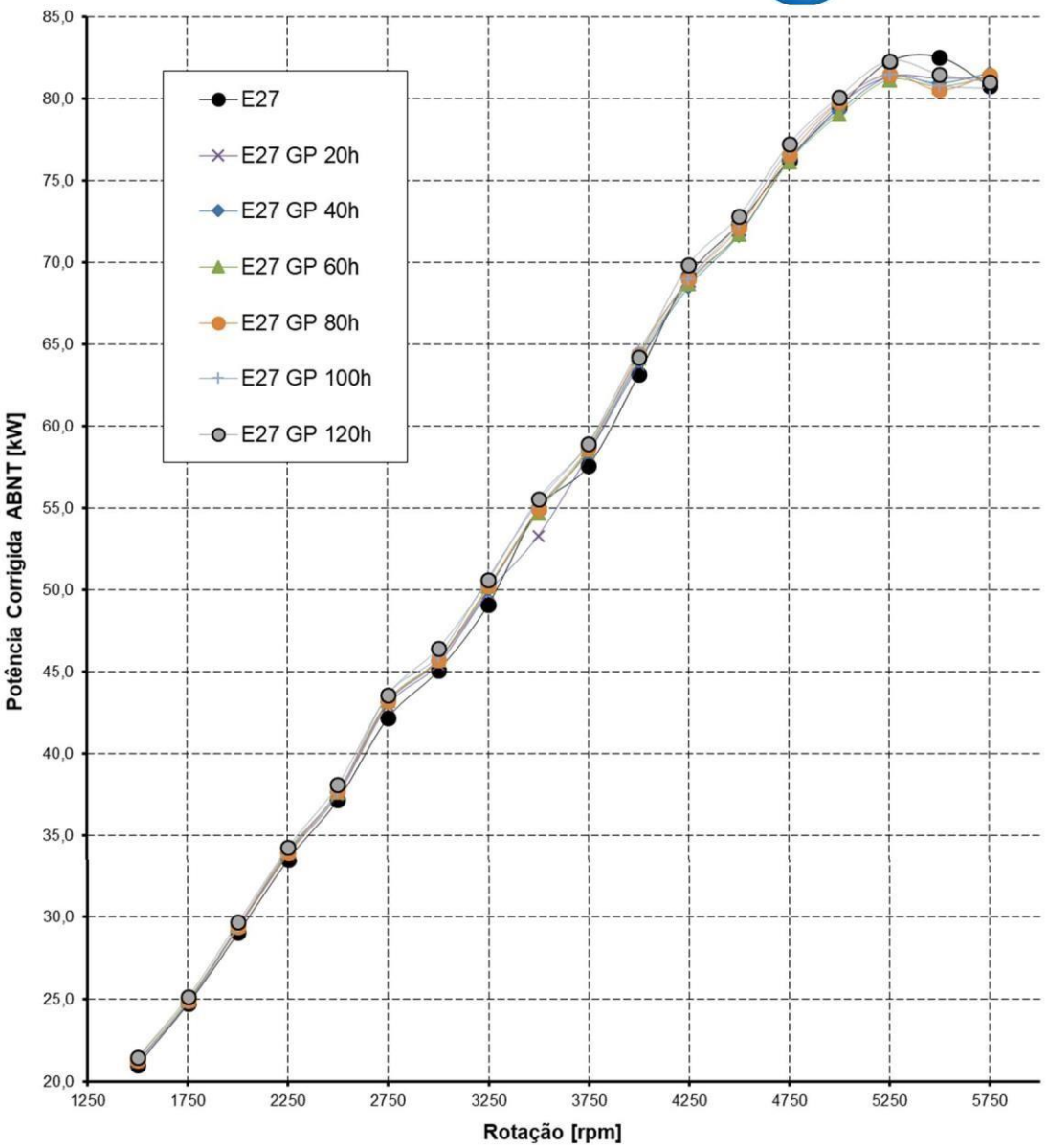

Figure 1. Corrected power produced by the engine as a function of rotation at full load, fueled with regular gasoline (E27) during the 120 hours of test with the use of *Green Plus* catalyst (E27 GP). Uncertainty of measurement: ±0.5 kW.

Table 2 shows the specific fuel consumption values as a function of rotation for the tests that range from the engine supplied with regular gasoline (*baseline*) to the final tests of the engine supplied with regular gasoline added to the *Green Plus* catalyst, after 120 hours of operation. Figure 2 presents the respective data graphically.

Table 2. Values of specific fuel consumption as a function of rotation at full load, obtained throughout the 120 hours test. Measurement uncertainty: ± 1,50 g/kW.h.

Rotation [rpm]	Specific fuel consumption [g/kW.h].						
	E27	E27 GP 20h	E27 GP 40h	E27 GP 60h	E27 GP 80h	E27 GP 100h	E27 GP 120h
1500	260,68	256,24	257,40	254,66	259,50	259,50	257,55
1750	258,18	253,62	256,43	255,20	255,22	256,52	254,17
2000	249,57	243,35	246,26	246,26	248,98	248,56	243,18
2250	244,56	242,61	241,46	240,82	247,42	244,07	241,03
2500	243,88	241,27	243,37	243,04	245,03	244,23	240,09
2750	244,55	241,21	243,97	242,71	245,49	241,35	239,17
3000	253,33	243,78	246,99	245,85	243,06	246,52	236,05
3250	246,74	242,27	243,66	243,93	244,18	242,42	242,24
3500	248,32	255,02	247,41	250,23	250,50	250,50	248,97
3750	249,44	249,91	250,77	249,91	252,17	251,10	246,14
4000	248,89	249,06	250,70	250,23	248,87	249,30	247,82
4250	253,32	255,01	257,99	257,31	258,41	256,77	253,43
4500	253,14	259,20	255,86	255,57	255,51	257,28	253,26
4750	258,26	258,13	255,74	256,53	256,01	254,61	252,17
5000	262,39	263,34	268,01	268,22	265,85	265,74	262,95
5250	268,47	274,46	273,60	273,38	271,31	272,64	266,82
5500	288,85	301,05	303,90	305,47	308,09	303,23	297,51
5750	310,07	320,70	316,99	318,25	320,36	321,72	317,12

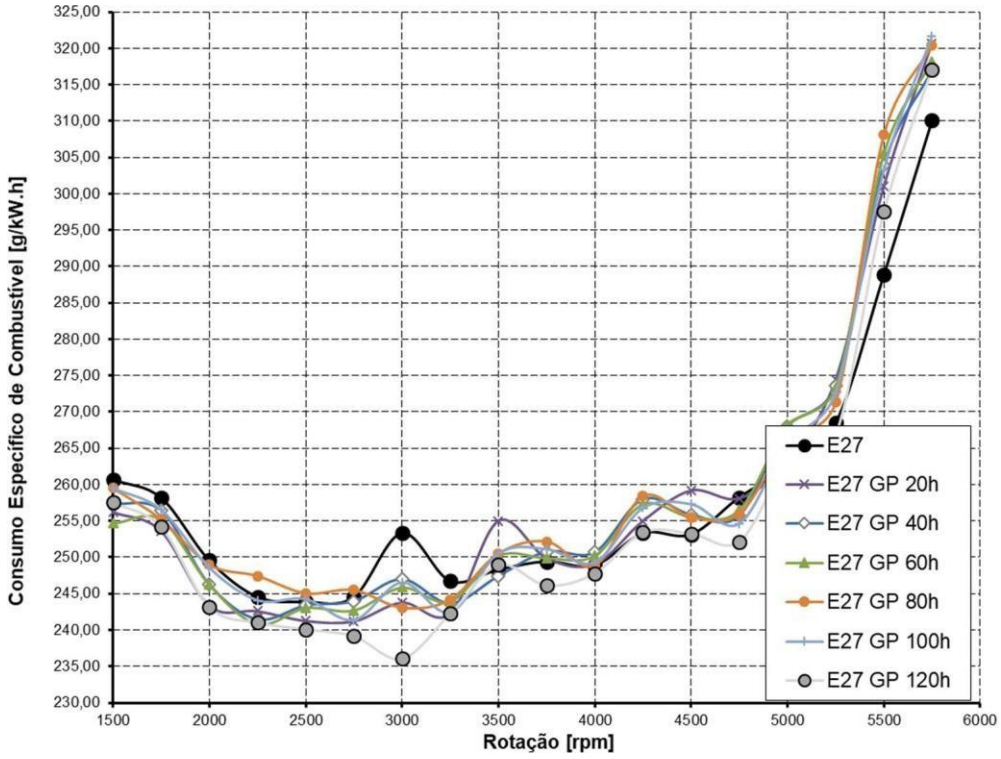

Figure 2. Specific fuel consumption of the engine as a function of rotation, at full load, fueled with regular gasoline (E27) during the 120 hours of test with the use of *Green Plus* catalyst (E27 GP).

Figures 3, 4 and 5 present, in a comparative manner, the results obtained for corrected power, corrected torque and specific fuel consumption as a function of rotation for the tests at full load with the engine supplied with regular gasoline (E27) and with gasoline plus Green Plus catalyst after 120 hours of operation (E27 GP 120h). These figures show the percentage differences obtained in each measured parameter, always in relation to the reference value (*baseline*).

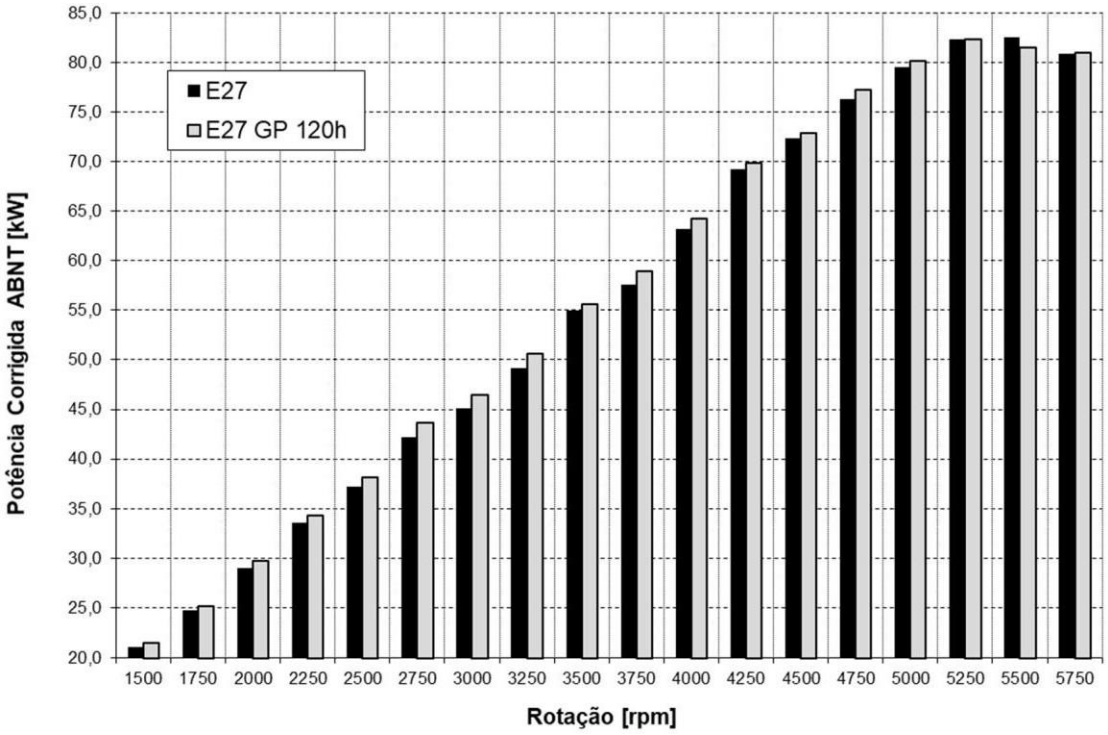

Figure 3: Comparison between the corrected power produced by the engine as a function of rotation, at full load, fueled with regular gasoline (E27) and after 120 hours of testing with gasoline with *Green Plus* catalyst (E27 GP 120h).

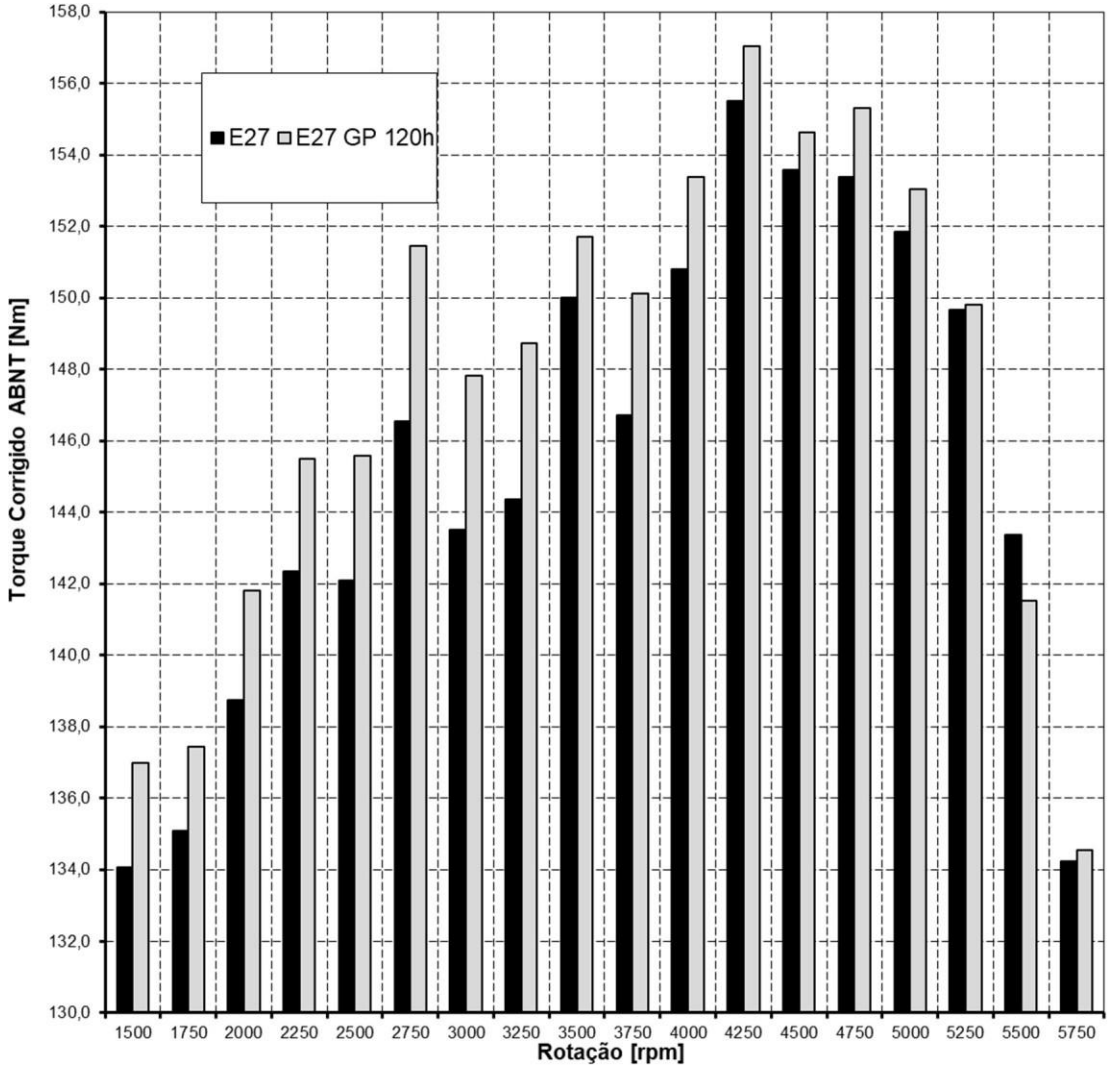

Figure 4: Comparison between the corrected torque produced by the engine as a function of rotation, at full load, fueled with regular gasoline (E27) and after 120 hours of testing with gasoline with *Green Plus* catalyst (E27 GP 120h).

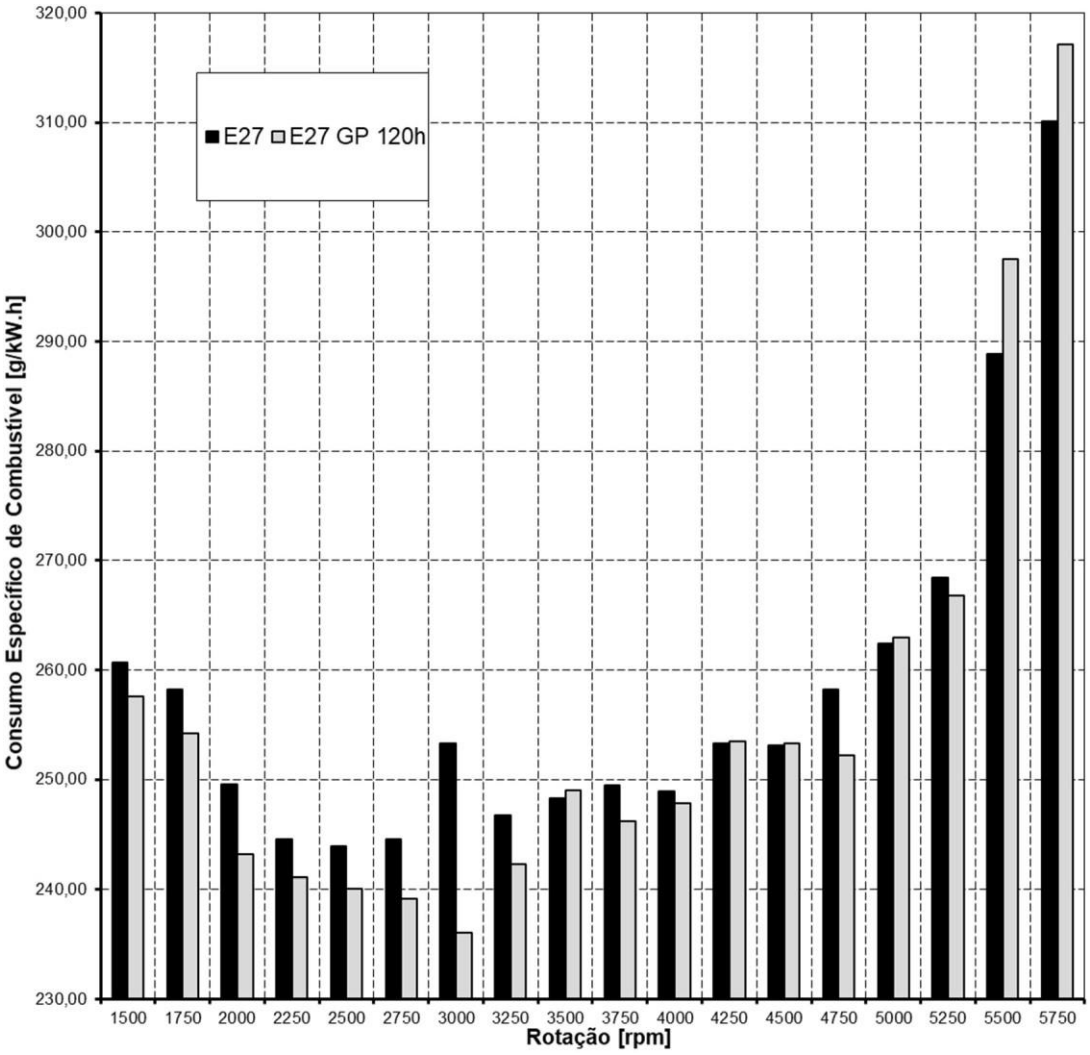

Figure 5: Comparison between specific fuel consumption of the engine as a function of rotation, at full load, supplied with regular gasoline (E27) and after 120 hours of testing with gasoline with *Green Plus* catalyst (E27 GP 120h).

3.2. Partial Load Tests (50%)

The tests at partial loads were performed from the data obtained at full load, setting the throttle valve opening at the minimum position sufficient to produce a torque equivalent to 50% of the nominal torque. Table 3 shows the torque values as a function of rotation used for the partial load tests, measured with the engine fueled with regular gasoline (*baseline*) and in the final tests, after 120 hours run with the engine fueled with regular gasoline plus the *Green Plus* catalyst.

Table 3. Torque at partial load used in the tests as a function of rotation at full load, fueled with regular gasoline (E27) and after 120 hours of testing with the use of *Green Plus* catalyst (E27 GP 120h). Measurement uncertainty: ± 0.2 %.

Rotation [rpm]	Torque in partial loads [N.m]	
	E27	E27 GP 120h
1500	66,0	65,1
1750	66,9	68,5
2000	69,0	69,2
2250	70,0	72,3
2500	70,4	71,3
2750	72,6	74,6
3000	71,7	71,5
3250	71,8	72,8
3500	74,4	74,7
3750	72,6	73,4
4000	74,6	75,9
4250	76,9	77,8
4500	76,7	78,4
4750	75,4	77,0
5000	75,1	76,8
5250	74,4	74,8
5500	71,1	72,4
5750	67,4	67,8

Table 4 shows the values of specific fuel consumption as a function of rotation for the tests with the engine supplied with regular gasoline (*baseline*) and the final tests of the engine supplied with regular gasoline added to the *Green Plus* catalyst, after 120 hours of operation. Figure 6 presents the respective data graphically.

Table 4: Specific fuel consumption values as a function of rotation at partial loads, obtained with regular gasoline (E27) and after 120 hours test. Uncertainty of Measurement: ± 1.50 g/kW.h.

Rotation [rpm]	Specific fuel consumption at part load [g/kW.h].	
	E27	E27 GP 120h
1500	262,86	251,71
1750	258,49	244,78
2000	253,54	241,09
2250	254,06	238,16
2500	254,16	238,61
2750	247,09	234,97
3000	251,16	239,38
3250	254,40	245,95
3500	255,90	246,02
3750	259,38	247,09
4000	259,48	250,20
4250	261,38	250,11
4500	261,06	252,25
4750	266,18	253,71
5000	269,75	255,10
5250	275,97	262,58
5500	289,76	270,73
5750	300,60	274,87

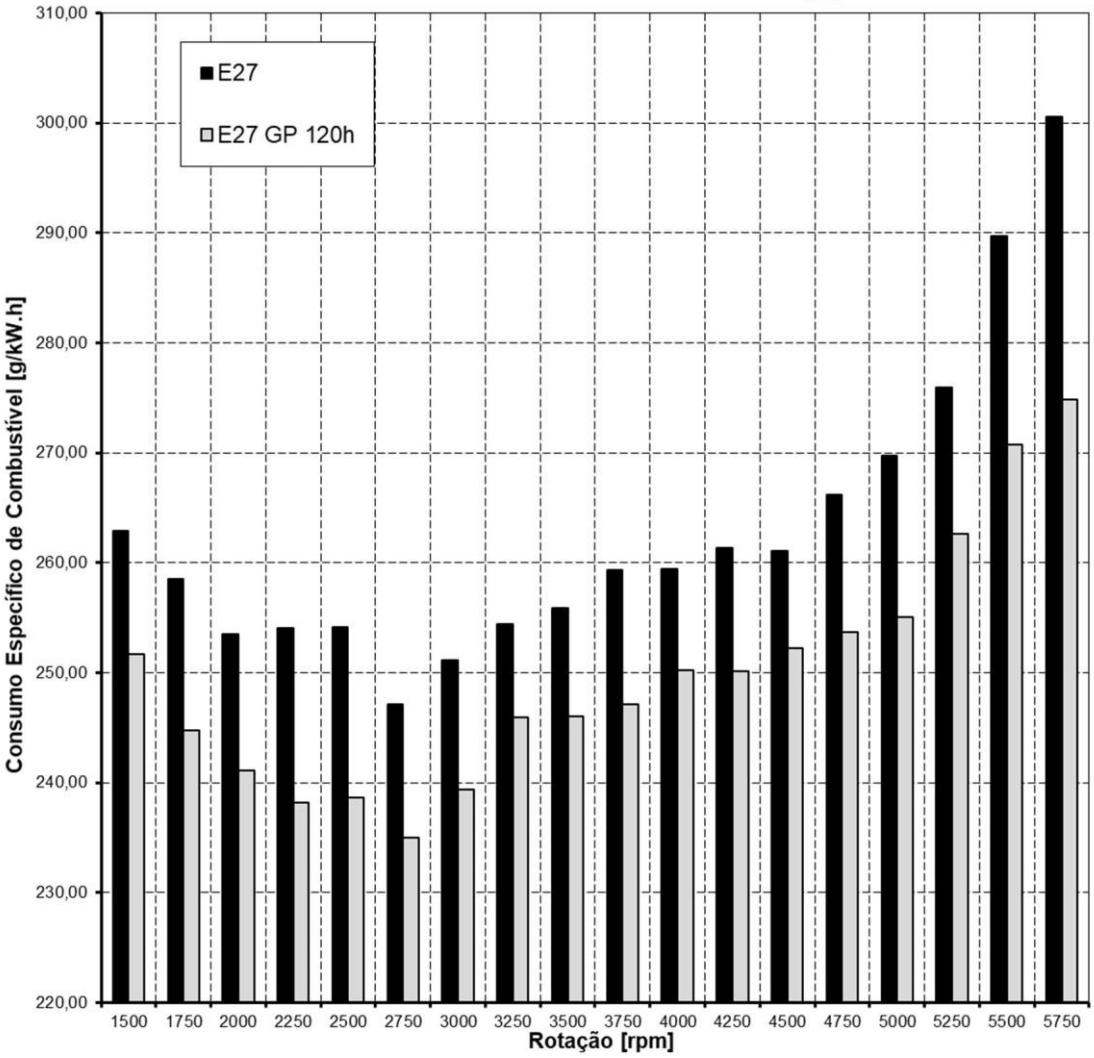

Figure 6. Specific fuel consumption as a function of rotation at partial loads, obtained with regular gasoline (E27) and after the 120 hours test with the use of *Green Plus* catalyst (E27 GP 120h).

4 - CONCLUDING REMARKS

This test report presents the results of the evaluation of the adoption of the *Green Plus* catalyst in the performance and fuel consumption of a spark ignition engine fueled with regular gasoline (E27), submitted to tests on a bench dynamometer. The experimental procedures were performed by the technical team of CTM/UFMG for the company Horeb Mercosul through a service provision request.

This report describes the methodology used and the results obtained during this evaluation. The fuel tested was regular gasoline purchased in the metropolitan region of Belo Horizonte/MG in its original condition and 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 test presented here.

The Methodology presented detailed the conditions of tests with the engine on the bench, being the rotation range between 1500 rpm and 5750 rpm, with an increment of 250 rpm and in load conditions of 100% (full load) and 50% of the maximum torque (partial load).

In the partial load tests, the aim was to evaluate fuel consumption at equivalent load (torque) demands at each rotation tested. The difference in the values measured in the partial load tests occurred due to the variation in the maximum torque developed by the engine when fed with regular gasoline (E27) and regular gasoline with *Green Plus* catalyst (E27 GP 120h).

The uncertainties associated with each of the measured parameters were presented in the respective tables, as well as the final results for each of them.